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EDITORIAL NOTES.

AN appeal has been issued on behalf of the Department of Geology at University College, Reading. Isolated departmental appeals are novel; but the times are deplorably changed, and institutions for teaching and research can barely hold their own, still less expand. But, whatever conditions may obtain in later life, youth must grow and develop, or perish. This Department is only 14 years old. During that brief period it has grown from an embryo with one junior lecturer and two elementary students to robust and active adolescence with a Professor, a Lecturer, 35 degree-students, about 70 elementary students and a Workers' Educational Tutorial Class. In spite of war-time conditions, 28 of its past students have passed the B.Sc. Examination of London University, and 3 others have taken Honours. Its activity in research is well known to our readers, for no less than 27 papers have appeared here. Almost as many, several of considerable bulk, have appeared elsewhere. The Geological Survey of New Zealand has sent its Fossil Echinoidea to be monographed from the Department; and research is in progress on many other topics.

All of this work and output has been accomplished with practically no material resources. There are no laboratories or museum—all classes are held in other departments. The sole erection belonging to the Department is an asbestos-fibre hut measuring 20 feet by 12 feet! Each year more students are attracted to Geology, and a critical stage has been reached. An effort is being made to raise £5,000, so that walls and a roof may be added to the reputation on which the Department lives at present.

The appeal, signed by Professor H. L. Hawkins and Dr. A. R. Dwerryhouse, has already met with generous response, but more help is urgently needed. Contributions, however modest, from those interested in the progress of geological knowledge, would give welcome encouragement. Cheques may be sent direct to the Professor; or, with a covering letter to explain their purpose, to the Registrar of the College.

ORIGINAL ARTICLES.

Notes on the Classification of Scottish and Moravian Teschenites.

By F. Walker, B.A.

(PLATE XI.)

THE following notes are based upon an investigation of the teschenites of the Midland Valley of Scotland, and are an attempt to produce a working classification of the teschenitic intrusions of that area. A comparison has also been made between the Scottish examples and those from some of the type localities of Moravia.

Earlier Classifications.

Before proceeding to consider the classification of the teschenites, it is perhaps advisable to give a very brief account of a few earlier attempts in this direction. The name teschenite was first used in 1861 by Hohenegger (1)[1], who applied it in a very general sense to certain igneous masses intrusive into Cretaceous strata in the neighbourhood of Teschen in Moravia. In 1866 Tschermak (2) separated from Hohenegger's teschenites the more basaltic-looking occurrences, to which he gave the name "picrite" on account of their high magnesia content (due to abundant olivine). The name "teschenite" was thus restricted to the more leucocratic varieties. Tschermak was also the first to recognize that analcite was an important constituent of teschenite, forming up to 27 per cent of the rock. He distinguished between hornblende and augite teschenites, thus making the first serious attempt at a classification.

The next great advance was made by Rohrbach (3) in 1885, but during the intervening years the great controversy over the presence of nepheline and the origin of the analcite in teschenites had arisen, nepheline-bearing teschenites from Moravia and the Caucasus being described by Tschermak and Rosenbusch, held that the analcite in teschenites was secondary, replacing nepheline—a view which he maintained throughout his later writings. Rohrbach investigated the teschenites of both Moravia and the Caucasus, but was unable to find any nepheline, even by micro-chemical tests. He considered that the analcite arose through decomposition of the plagioclase, which it frequently replaced. He divided the teschenites primarily into two groups, (*a*) ophitic and (*b*) non-ophitic. The latter group was further divided into several sub-groups on textural and mineralogical grounds. Hornblende was a variable but ubiquitous constituent of the second group, but was absent from the first or diabasic group. Rosenbusch recognized the value of this exceedingly careful research, but remained unconvinced that the analcite originated from plagioclase. In his last (1907) edition of *Mikroskopische Physiographie*, ii, p. 431,

[1] Figures in parentheses refer to bibliography at end of paper.

he expresses his conviction that the teschenites are to be reckoned as altered theralites.

Teall (4) was the first to recognize teschenitic intrusions in the Midland Valley of Scotland, and since his description of the Carcraig rock in 1888, numerous fresh occurrences of this type have been investigated.

In recent years the work of Bailey, Campbell, Tyrrell, and others has adequately demonstrated the primary nature of most of the analcite in these teschenites. It has also been observed that when nepheline occurs in teschenites it does *not* alter into analcite. To quote Tyrrell: "Nepheline does occur in some teschenites, and is often altered; but it does not alter into analcite. Analcite has been shown to be a primary constituent of teschenite and many other analcitic igneous rocks; but owing to its aqueous constitution, and the consequent mobility and chemical activity of its solutions, or magma, it is an extremely efficient agent of paulopost alteration in previously formed mineral constituents, with the result that the analcite itself has been regarded as secondary. In other words, the analcite is not due to the alteration of the other minerals, but the alteration is due to the analcite."

To Tyrrell (5) we owe the classification of the West of Scotland teschenites into three groups:—

(1) Glasgow type.
(2) Galston type.
(3) Cathcart type with nepheline.

Some of the East of Scotland teschenites have, however, no place in this classification, notably the rock of Spalefield, near Anstruther.

Definitions of Teschenite.

It is essential to have clear and comprehensive definitions of rock-types before attempting their classification. Modern petrological treatises are unkind to the teschenites in this respect, and the writer has not yet found two authors who give the same definition.

Hatch (6) gives the following simple definition: "The teschenites or analcite-dolerites are dyke rocks essentially composed of plagioclase felspar, augite, and analcite. Olivine is also a frequent constituent."

The objections to this definition are, first, the inclusion of the analcite-dolerites under the name teschenites, and second, the absence of any mention of amphibole as a frequent constituent. The vast majority of rocks described as analcite-dolerite have a much lower alkali percentage and are more closely related to the olivine-dolerites.

According to Iddings (7), "Teschenites are analcite-theralites composed of lime-soda felspar, analcite, augite, barkevikitic amphibole, and some biotite and apatite. The analcite may be altered nepheline. The texture is medium-grained equigranular."

When discussing theralites, Iddings points out that many rocks which have been described as teschenites are, in reality, altered theralites. Thus Iddings inclines towards the view of Rosenbusch that the analcite is derived from the decomposition of nepheline—a view which is now discredited by the majority of petrologists. A decided objection to the above definition is that the presence of barkevikite is considered essential.

Holmes (8) defines a teschenite as "an alkali-rich variety of analcite-dolerite characterized by the presence of idiomorphic purple augite or aegirine-augite, and generally containing soda-amphiboles such as barkevikite".

The only important objection to this definition is the use of the words idomorphic purple augite, for in a great many teschenites the augite, far from being idiomorphic, is strongly ophitic. Moreover, as Tyrrell points out, the term dolerite should always connote ophitic texture.

Harker (9) does not define the term teschenite, but includes the teschenites in the gabbro group, commenting upon the difficulty of drawing a line between the teschenites and the theralites.

As there are a great many textural varieties of teschenites, the ideal definition would seem to be one on a mineralogical basis only. The writer suggests the following definition as an improvement on any of the foregoing.

"Teschenites are rocks consisting essentially of plagioclase felspar (which is partially or wholly analcitized), titanaugite, and analcite. Barkevikite is often present, sometimes reaching a greater abundance than the titanaugite, and olivine is a frequent constituent." Accessory minerals may include nepheline, zeolites, alkali-felspar, aegirine-augite, biotite, apatite, ilmenite, and pyrites.

This definition has the advantage of drawing a sharp line between the analcite-dolerites (including the Crinan type (10)[1] and the augite-teschenites, without the introduction of any arbitrary condition. Analcite in certain analcite-dolerites may be observed filling cracks in the larger plagioclases, but the patchy replacement of plagioclase so characteristic of the teschenites is never seen.

Relationship of Teschenites to Theralites and Camptonites.

With increase of nepheline and decrease in the quantity of analcite the teschenites grade into the theralites, for which Lacroix (11) has recently produced a classification. The nepheline-teschenites of Cathcart and Lugar are "half-way houses" between the two types, and may be classed either with the teschenites or with the luscladite or berondrite groups of the theralites.

With diminution of the amount of analcite the non-ophitic and sub-ophitic hornblende-teschenites show a gradual passage into camptonites. Such camptonites are found in Iona and as segregations in teschenite sills at Whitehouse Point, Inchcolm, and else-

[1] See also Pl. XI, Fig. 4.

where. These segregations are of much finer grain than the normal rock, and show well-marked ocellar structure.

Suggested Classification of Scottish Teschenites.

The following classification of the Scottish teschenites is suggested :—

(*a*) *Porphyritic or Basalt Type.*

Characterized by conspicuous phenocrysts of fresh olivine and titanaugite, frequently forming glomero-porphyritic aggregations. The grain is fine to medium. (See Pl. XI, Fig. 1.)

(*b*) *Ophitic or Dolerite Type.*

Typically non-porphyritic and characterized by well-marked ophitic or sub-ophitic relationship between the titanaugite and plagioclase. The olivine is invariably serpentinized and the grain is medium to coarse. (See Pl. XI, Fig. 2.)

(*c*) *Non-ophitic or Gabbro Type.*

Typically non-porphyritic and characterized by even-grained hypidiomorphic texture. In the varieties rich in analcite both the titanaugite and barkevikite are markedly euhedral. Ophitic structure is absent and the olivine invariably serpentinized. The grain is medium to coarse. (See Pl. XI, Fig. 3.)

The above division of the teschenites into three groups has been made on textural grounds, each of the primary groups being further divided into two sub-groups :—

(1) Varieties with hornblende (barkevikite).
(2) Varieties without hornblende.

The distribution of the barkevikite is, however, so exceedingly capricious in some rocks that the value of this further division is doubtful. It is convenient to refer to teschenites containing barkevikite as hornblende-teschenites, the term augite-teschenite being reserved for varieties without barkevikite. A short description follows of typical rocks in each division.

(*a*) The rock of Spalefield, near Anstruther, may be taken as typical of this division. A detailed description of this hornblende-teschenite has been given by Dr. Flett (12) and is therefore unnecessary here. The barkevikite is not abundant, but is a fairly constant constituent, forming small idiomorphic prisms in the groundmass. Some of the titanaugite phenocrysts show a purple margin round a green centre—a reversal of the usual state of affairs.

Only one other Scottish teschenite known to the writer may be placed without hesitation in group (*a*). This is the augite-teschenite sill of Obelisk Hill, Aberdour, which has not yet been described. The outcrop possesses the shape of an inverted pot-hook and stretches from the west of Aberdour harbour to the east of Braefoot Point.

The rock shows little variety, is usually very fresh, and is of

medium grain. Under the microscope large rounded phenocrysts of unaltered olivine form the most conspicuous constituent. There are also a few smaller phenocrysts of purple titanaugite showing idiomorphism and twinning. The groundmass consists of small idiomorphic titanaugite prisms, together with small plagioclase laths and abundant analcite, usually turbid. Minor constituents include alkali-felspar, doubly refracting zeolites, biotite, ilmenite, and apatite, this last mineral forming hexagonal prisms of a much larger size than usual. The analcite has in places corroded the plagioclase, but the latter mineral may be seen quite fresh and appears to range from labradorite to oligoclase. Where the analcite comes into contact with other zeolites, it invariably presents idiomorphic faces towards them, but is allotriomorphic towards all the other minerals, filling the interspaces of the rock, as do the other zeolites. A superficial examination of sections from the summit of Obelisk Hill showed the apparent anomaly of small titanaugite crystals enclosed in large phenocrysts of olivine. On a more detailed examination, however, it was seen that after the olivine had solidified, the magma made its way along the cracks in that mineral and crystallized out finally as titanaugite and felspar. In these sections the amount of the doubly-refracting zeolites increases at the expense of analcite. Nepheline was not observed in either the Aberdour or the Spalefield rocks, and in this respect they differ from the nepheline-teschenite of Cathcart, which, if it is to be grouped with the teschenites at all, must come under this division. The Cathcart rock has, however, strong theralitic affinities. Olivine forms an abundant constituent of all the above rocks, but diminishes in amount in specimens belonging to the other two groups.

(*b*) This group includes a very large proportion of the Scottish teschenites. As an example of a true ophitic type, the teschenite of Gullane Head may be taken, for it is a well-known rock and has been carefully described by Professor Young (13). Hornblende occurs sporadically in this intrusion. A very fresh example of a sub-ophitic type is afforded by the augite-teschenite of Mons Hill. By this is meant the exposures on the eastern slopes of Mons Hill itself, and not the rock of Crossall Hill or Whitehouse Point. This teschenite shows analcitization of the plagioclase clearly and appears to be rich in soda-orthoclase. Olivine, pseudomorphed by brownish-green serpentine, is quite common, and biotite is a fairly abundant constituent. Some of the smaller titanaugite crystals are nearly euhedral, but the larger ones show a sub-ophitic relationship with the felspar and sometimes enclose small laths of plagioclase. No hornblende is present, but in one section a small crystal of fresh nepheline showing a rectangular outline was noted. A similar isolated crystal of nepheline was observed in the teschenite of Dundas. The rock from the second intrusion east of the mouth of the River Almond is a finer grained teschenite

of similar type, but contains more analcite and, in places, some barkevikite, both in parallel growth with the titanaugite and as separate prisms. Group (*b*) includes the majority of the rocks which come under the Glasgow and Galston types of Tyrrell.

(*c*) The rocks of group (*c*) appear to be confined to the West of Scotland. The rock from the margin of the Mons Hill sill at Whitehouse Point has been described as a non-ophitic teschenite (14), but cannot now be so regarded owing to the discovery by the writer of nepheline as an important constituent. This mineral is certainly present in sufficient abundance to justify the inclusion of the rock among the theralites. To obtain a true non-ophitic hornblende-teschenite we must turn to the Lugar sill, which has been exhaustively described by Mr. Tyrrell (15). In this complex intrusion it is found that the rock named lugarite fulfils the necessary conditions, and may be regarded as a hornblende-teschenite which is extremely rich in analcite. Nepheline is not an important constituent of the sections possessed by the writer, and barkevikite is present in greater quantity than titanaugite. Pseudomorphs after olivine are rare or absent.

The teschenite of Cranhill quarry, near Shettleston, affords an excellent example of a non-ophitic augite-teschenite. Euhedral prisms of titanaugite, showing well-marked hour-glass structure, are set in an aggregate of analcite and plagioclase. The plagioclase is largely analcitized. Green pseudomorphs after idiomorphic olivine are of frequent occurrence, and minor constituents include alkali-felspar, biotite, apatite, and ilmenite. In the hand specimen the rock is very dark in colour.

Moravian Teschenites.

In order to make a comparison between the Scottish and Moravian teschenites, ten sections of the latter were obtained. Five were loaned from the collection of the Sedgwick Museum in Cambridge through the kindness of Dr. Harker, three were taken from a collection illustrating Rosenbusch's *Mikroskopische Physiographie*, while the remaining two were purchased from Voigt and Hochgesang. Two of these ten slides had unfortunately to be rejected, as one from the Rosenbusch collection, labelled Neutitschein, was a monchiquite, and another purchased from Voigt and Hochgesang labelled Söhla, was a camptonite. Of the other eight sections, five were coarse, markedly ophitic augite-teschenites, greatly resembling many of the coarser Scottish rocks and almost indistinguishable from some parts of the Mons Hill sill. Four were from Teschen and one from Boguschowitz. The remaining three sections were all non-ophitic. One from Teschen was an augite-teschenite very similar to the Cranhill rock and showing the same euhedral augites with hour-glass structure. The second section (from Boguschowitz) showed an equally close resemblance to Tyrrell's lugarite, the euhedral barkevikites and titanaugites being set in

a turbid aggregate of leucocratic minerals in the same fashion. In the Moravian rock, however, the barkevikites are partly chloritized and the surrounding minerals stained green. The third and last section (from Pod Rudau) resembles the second, but is fresher. The large euhedral barkevikites and titanaugites are unaltered, and the latter have a very pronounced green margin. The leucocratic minerals consist of analcite and other zeolites, which often replace plagioclase and alkali-felspar. A few small crystals of soda-amphiboles and pyroxenes are also present, and large brownish apatites are common. The rock has a certain resemblance to the analcite-syenite of Howford Bridge, but is richer in zeolites and barkevikite. These last three sections all fall into Rohrbach's non-ophitic group.

According to the writer's classification, the five ophitic sections would all fall into group *b* (doleritic), while the non-ophitic ones might be placed with equal confidence in group *c* of the non-ophitic gabbro-like teschenites.

It is interesting to note the close resemblance between the Moravian rocks and our Scottish types, and to find lugarite represented in the former province. From the very limited material available, it appears that the Scottish classification is applicable to the Moravian teschenites.

In conclusion, the writer desires to express his great indebtedness to Dr. Harker and Dr. Thomas for the loan of sections, and to Dr. Campbell, Mr. Balsillie, and Mr. Tyrrell for much kind assistance and advice.

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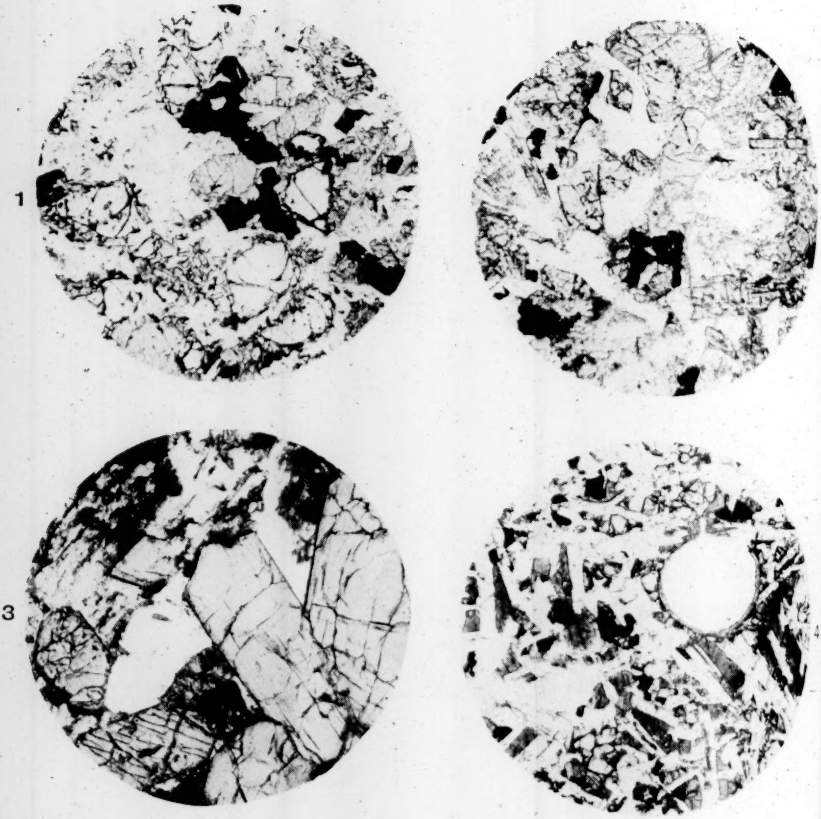


TYPES OF SCOTTISH TESCHENITES.

To face p. 219.

EXPLANATION OF PLATE XI.

FIG.

1.—Porphyritic or "basalt" type of teschenite. Obelisk Hill, Aberdour. Ordinary light, magnified 25 diameters. Phenocrysts of fresh olivine and titanaugite, and large crystals of iron ore set in a turbid ground-mass of felspars, titanaugite, and zeolites.

2.—Sub-ophitic "dolerite" type of teschenite. Shore quarter-of-a-mile east of Cramond village. Ordinary light, magnified 25 diameters. Sub-ophitic crystals of titanaugite, clear patches of analcite, and iron ores are conspicuous in a turbid aggregate consisting mainly of analcitized plagioclase.

3.—Non-ophitic "gabbro" type of teschenite. Cranhill, Glasgow. Ordinary light, magnified 25 diameters. Large euhedral titanaugites showing hour-glass structure set in aggregate of clear analcite, turbid analcitized plagioclase, iron ores, and serpentine.

4.—Crinanite, Mingulay, Outer Hebrides. Ordinary light, magnified 35 diameters. Note the dark coloured strongly ophitic pyroxene, the granular olivine, and the freshness of the leucocratic minerals as compared with teschenites. A circular analcite-filled vesicle is conspicuous.

Classification and Age of the Analcite-bearing Igneous Rocks of Scotland.

By G. W. Tyrrell, A.R.C.Sc., Ph.D., F.G.S., F.R.S.E., Lecturer in Geology, University of Glasgow.

THE Midland Valley region of Scotland contains the world's largest known development of igneous rocks carrying primary analcite. These rocks have been described in several publications during the last fifteen years, and some new rock-types have been defined.[1]

The analcite-bearing rocks are concentrated in four main areas: Fife and the Lothians; the Glasgow district; Ayrshire; and the West Coast from the Clyde region up to the Outer Hebrides. In the first three of these areas the age of most of the analcitic igneous rocks is Late-Carboniferous or Permian; in the last-named area they are most probably connected with Cainozoic volcanic activity.

The Late-Palæozoic examples occur almost entirely as sills usually not more than 200 feet in thickness; the Cainozoic masses appear both as sills and thick dykes. Volcanic or lavaform representatives of these rocks occur in numerous volcanic vents, and in two small lava fields (Mauchline, Ayrshire; Thornhill, Dumfriesshire).

A close scrutiny of the whole assemblage of analcitic rock-types in Scotland makes it clear that there two series or suites which are tolerably distinct from the petrographical standpoint, and also in respect to geological age and relations. These may be respectively called the *teschenite* series and the *crinanite* series from their most characteristic and abundant rock-types. Both the magmas represented by these rock-types may be regarded as the starting points for differentiation in two or three directions, resulting in the production of large and varied assemblages of related analcitic igneous rocks.

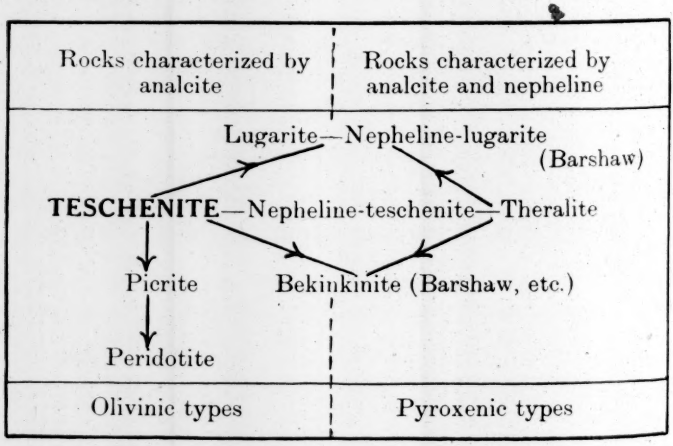
[1] For the principal references see the bibliography appended to the paper. In the text these publications are referred to by number.

The Teschenite Series.

Teschenite is analcite-gabbro, just as theralite is nepheline-gabbro and missourite is leucite-gabbro. It consists of labradorite (An 50 to An 70), analcite, titanaugite, olivine, iron-ores, and apatite. Soda-orthoclase often accompanies analcite as an important accessory; and a red soda-hornblende (barkevikite) is associated with the pyroxene either as a paramorphic alteration product or as a primary mineral. A reddish biotite may accompany the titaniferous iron-ore. The rock is typically mafelsic and may be very coarse-grained, but usually it is medium- to fine-grained, with sub-ophitic texture, and passes to doleritic and basaltic varieties in the smaller sills and towards the margins of the larger masses. Full descriptions of representative examples of this rock-type are to be found in many of the publications cited in the Bibliography (see especially Numbers 1, 2, 4, 5, 8, and 12).

Differentiation from teschenite in the ultrabasic direction by the concentration of the mafic constituents leads to the formation of picrite (*sensu stricto*),[1] and finally to peridotite when olivine is the principal mafic constituent. In the alkalic direction differentiation from teschenite leads to the formation of the highly analcitic type known as lugarite.

A subsidiary type of differentiation, with the relative concentration of pyroxene or amphibole as its main feature, and a tendency for nepheline partly to take the place of analcite, brings about such rock-types as nepheline-teschenite (Cathcart), theralite (Lugar), and bekinkinite (Barshaw; Carskeoch, etc.). The relationships of the rocks of the teschenite series are diagrammatically displayed in the following scheme :—



[1] The original *picrite* was an ultrabasic differentiate from the teschenites of Moravia. G. Tschermak, *Sitzungsber. k. Akad. Wien*, liii, 1866, p. 262.

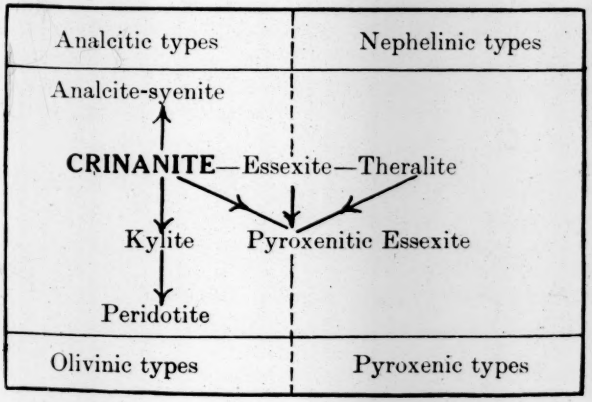
The Crinanite Series.

Crinanite was first named and described by Dr. J. S. Flett (Refs. 6 and 7) from the centre of distribution (Crinan Canal, Argyllshire) of certain olivine-analcite-dolerite dykes which are believed to be of Cainozoic age. These are ophitic dolerites with purple titan-augite, labradorite, abundant olivine, iron-ores, and a small quantity of interstitial analcite (or radial zeolites) and alkali-felspar. In the great sills of Ayrshire, Arran, and Bute, the texture becomes coarsely gabbroidal, and even pegmatitic with pyroxene crystals 3 inches in length (Clauchland Point, Arran). Gradual transitions may be traced from crinanites with indubitable fresh primary analcite to ordinary olivine-dolerites, which, however, betray their affinities by their purple titanaugite, and occasionally by the finding of a rare interstitial patch of analcite, radial zeolites, or alkali-felspar.

Assuming the parent magma to have the composition of crinanite differentiation in this series follows courses parallel to those in the teschenite series. In the ultrabasic direction the concentration of olivine leads first to the rock-type described under the name of *kylite* (Ref. 8), and finally to a peridotite which, however, is quite different in character from the ultrabasic end-product of the teschenite series. In the alkalic direction the final differentiate is *analcite-syenite* which, again, is quite a different type from lugarite, the corresponding rock of the teschenite series.

A variation in which pyroxenes are concentrated in preference to olivine, and in which nepheline becomes a prominent constituent, is seen in the porphyritic essexites (Lennoxtown, Crawfordjohn, Patna), good typical theralites (Ochiltree, etc.), and pyroxenitic essexites (Crawfordjohn, etc.).

The interrelationships of these types are exhibited in the diagram below. The parallelism between the diagrams for the two series should be noted. No nepheline-bearing type is known as yet in the crinanite series corresponding to the nepheline-lugarite of Barshaw.



Differences between the Teschenite and Crinanite Series.

The chief differences are the greater abundance of analcite in the teschenite series, of potassic felspar and olivine in the crinanite series. Plagioclase felspar also tends to be relatively more abundant in the last named, but it becomes highly sodic in composition towards the alkalic end of the series, while in the teschenite series the plagioclase remains of labradorite composition throughout. A subsidiary difference is the greater prominence of barkevikite and apatite in the teschenite series, a feature which is probably genetically connected with the relatively greater amount of water which is retained in the teschenite series as compared with the crinanite. Some of the coarser crinanite types in the thick sills of Arran contain almost as much analcite as a typical teschenite, but are distinguished by the abundance of fresh olivine.

The differences between the two series are graphically displayed in the variation diagrams Figs. 1 and 2. These have been drawn from the measured and computed modes of two typical rock series, the teschenite diagram (Fig. 1) mainly from the Lugar rocks, the crinanite diagram (Fig. 2) from the kylites and crinanites of the Dalmellington-Patna district and the analcite-syenite of Mauchline. The percentages of mafic constituents in the rocks have been plotted along the abscissæ, and other mineral constituents along the ordinates. It is believed that this procedure gives the best picture of the general course of differentiation; since this process, by whatever mode it is conceived to take place, tends in general to the separation of the calc-ferro-magnesian or mafic constituents (chiefly olivine and pyroxenes) from the alkalic constituents (alkali-felspars and felspathoids) and quartz.

The curves are based mainly on the olivinic and analcitic branches of the two series, i.e. the rocks found on the left-hand sides of the above diagrams. Some of the pyroxenic essexites and theralites, and bekinkinite, do not fit either group of curves very well. They tend to fit the crinanite curves for olivine and orthoclase, but are nearer the teschenite curves for analcite (and nepheline) and plagioclase. Thus in some respects the pyroxenic types are intermediate between the two series.

The chemical characters of the two series are exhibited in Tables I and II, in which are collected representative analyses of the main rock-types.

Age Relations.—In discussing the perplexing question of the ages of the analcite-bearing rocks of Scotland, the following five groups must be considered separately:—

1. Teschenite series of Ayrshire, Glasgow, the Lothians, and Fife.
2. Analcite-syenite—crinanite—kylite—peridotite sills of Ayrshire.
3. Crinanite—kylite sills of Arran and Bute.
4. Large crinanite dykes of the mainland and islands of the Clyde Estuary.
5. Crinanite dykes of the western coasts and islands.

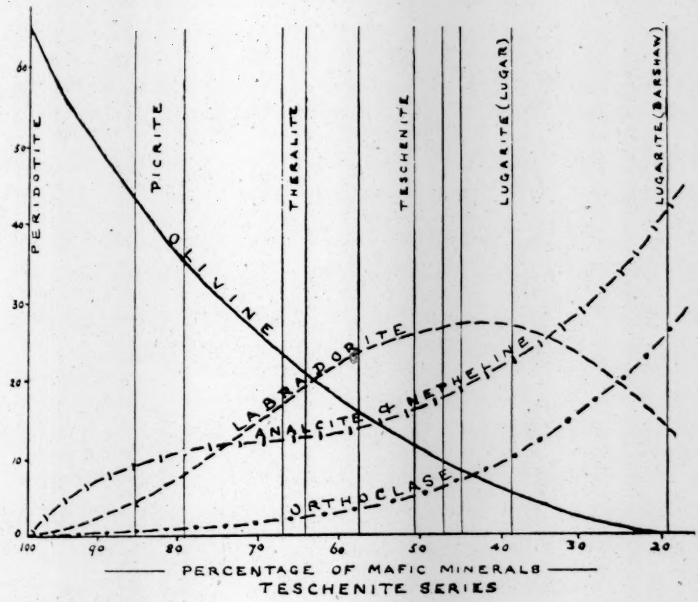

PERIDOTITE
PICRITE
THERALITE
TESCHENITE
LUGARITE (LUGAR)
LUGARITE (BARSHAW)
OLIVINE
LABRADORITE
ANALCITE & NEPHELINE
ORTHOCLASE
PERCENTAGE OF MAFIC MINERALS
TESCHENITE SERIES

FIG. 1.

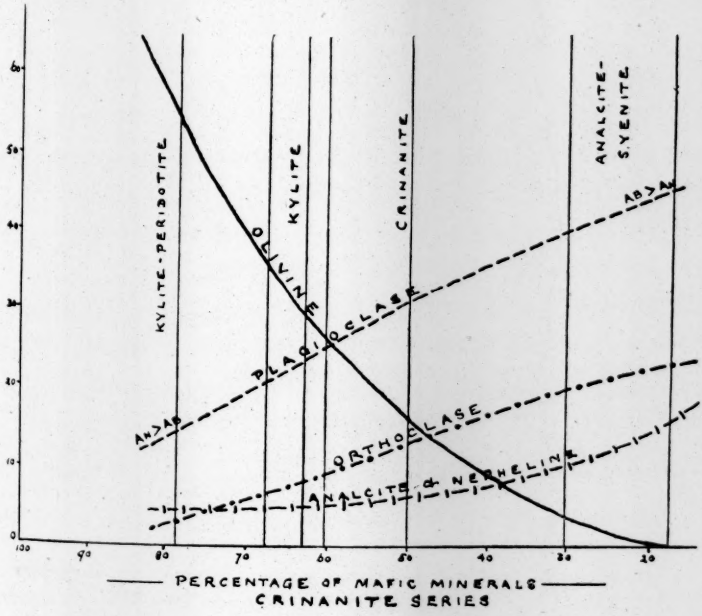

KYLITE-PERIDOTITE
KYLITE
CRINANITE
ANALCITE-SYENITE
OLIVINE
PLAGIOCLASE
ORTHOCLASE
ANALCITE & NEPHELINE
PERCENTAGE OF MAFIC MINERALS
CRINANITE SERIES

FIG. 2.

Table I.—The Teschenite Series.

	(1)	(2)	(3)	(4)	(5)
SiO_2	46·44	45·57	44·47	40·35	40·87
TiO_2	1·45	2·41	2·73	2·12	2·85
Al_2O_3	16·36	14·95	7·59	3·75	16·23
Fe_2O_3	4·91	2·82	6·25	3·53	1·31
FeO	5·89	7·35	9·57	9·86	7·37
MnO	·19	·31	·49	·20	·64
MgO	2·20	6·19	11·93	25·69	9·83
CaO	5·25	8·27	10·24	4·64	11·13
Na_2O	8·81	4·33	4·27	3·14	2·78
K_2O	1·59	2·16	1·46	·80	·53
H_2O+	4·83	3·93	·73	5·28	4·28
H_2O-	1·30	·97	·48	·83	1·35
CO_2	none	·18	tr.	tr.	·38
P_2O_5	·87	·67	·54	·25	·52
(BaSr)O	·09	·07	n.d.	·06	none
Rest	—	—	—	—	·27
	100·18	100·18	100·75	100·50	100·34

(1) Lugarite, average of two analyses.
(2) Teschenite, average of five analyses.
(3) Picrite, Lugar.
(4) Peridotite, Lugar.
(5) Bekinkinite, Barshaw. The "Rest" includes FeS_2, ·21; (NiCo)O, ·06; and Li_2O, ? tr.

Table II.—The Crinanite Series.

	(1)	(2)	(3)	(4)	(5)
SiO_2	56·44	44·69	44·70	44·18	43·94
TiO_2	1·16	·46	2·34	1·30	2·45
Al_2O_3	15·54	14·17	14·50	10·67	14·03
Fe_2O_3	3·27	3·35	2·95	·97	1·95
FeO	3·67	10·86	8·05	10·03	11·65
MnO	n.d.	·31	·30	n.d.	·32
MgO	1.73	6·41	7·82	17·77	10·46
CaO	4·16	10·28	11·25	9·75	8·99
Na_2O	5·81	3·64	4·10	2·37	2·68
K_2O	4·27	2·01	1·71	1·23	·33
H_2O+	2·06	2·53	1·47	·97	2·31
H_2O-	·44	1·05	·24		·85
CO_2	·97	none	·11	tr.	·16
P_2O_5	·83	·45	·71	·38	·20
(BaSr)O	n.d.	tr.	tr.	n.d.	none
Rest	—	—	—	—	·10
	100·35	100·21	100·25	99·83	100·42

(1) Analcite-syenite, Howford Bridge, Mauchline.
(2) Crinanite, Howford Bridge, Mauchline.
(3) Porphyritic Essexite, average of two analyses.
(4) Kylite, Benbeoch, Dalmellington.
(5) Crinanite, Cainozoic dyke, Inver Lodge, Jura. The "Rest" includes FeS_2, ·04; Fe_7S_8, ·06; Cr_2O_3, tr.

1. Teschenite Series of Ayrshire, Glasgow, the Lothians, and Fife.

Ayrshire.—There are two main groups of teschenite occurrences in Ayrshire; one in the district of Lugar and Old Cumnock,

embracing the Lugar, Craigens, Glaisnock, Glengyron, Craig Farm, Carnevan Hill, and Carskeoch Hill intrusions; and another in North Ayrshire, including the sills of Galston, Stewarton, Ardrossan, and Saltcoats. These mainly intersect the Carboniferous sediments up to the Coal Measures. The Polbaith sill (Galston) appears to cut an agglomerate vent which may be of Permian age, but this occurrence requires further investigation. The critical locality, however, is that of Carskeoch Hill, near Patna, where rocks of the teschenite series, along with a crinanitic type, occur as intrusions in a Permian volcanic vent. This remarkable assemblage is dealt with in more detail later (p. 256).

Glasgow District.—The Glasgow teschenites intersect the strata of the Millstone Grit and Coal Measures.

The Lothians.—According to the Edinburgh Memoir (4, p. 275), the alkaline, analcite-bearing intrusions belong to an earlier set (quartz-dolerites being the later) which are regarded as contemporaneous with, and allied to, the Lower Carboniferous lavas. They are believed to represent the underground part of this igneous episode. This conclusion is supported by their absence above the Index Limestone horizon of the Carboniferous Limestone Series.

At Inchcolm, Campbell and Stenhouse found a dyke of quartz-dolerite cutting the teschenite-picrite sill of that island. The conclusion that the teschenites are prior to the quartz-dolerites is reinforced by similar evidence afforded by a quarry at Ochiltree Mill, south of Linlithgow (4, p. 275; and *Ann. Summ. Prog. Geol. Surv. for* 1904, 1905, p. 118).

The view that the alkaline intrusives are related to Lower Carboniferous vulcanicity is also taken in the East Lothian Memoir (3, p. 99), although most of the basic alkaline, analcite-bearing rocks are intrusive into strata younger than the latest trachytic lavas of that region. The Gosford Bay teschenite intersects beds of the lower part of the Carboniferous Limestone Series. The monchiquites and analcite-basalts of East Lothian are remarkably similar to the rocks intrusive into the Permian volcanic vents of Fife and Ayrshire. It is at least a possibility, therefore, that they are really connected with late-Carboniferous or Permian vulcanicity (14, p. 358).

Fife.—The eighty volcanic vents of Fifeshire between Largo and St. Andrews have been assigned by Sir A. Geikie with considerable probability to the Permian.[1] In all respects they are identical with the Permian vents of Ayrshire, and carry small intrusions of basic analcite- or nepheline-bearing rocks. The great assemblage of sills which occurs in central Fife contains rocks of varied petrographical types. Some are quartz-dolerites; others, such as that of Spalefield, are of teschenitic affinities.[2] An examination of the Survey slide of this rock shows that it has resemblances to the

[1] "Geology of East Fife": *Mem. Geol. Surv.*, 1902, p. 279.
[2] Ibid., p. 392. See Ref. 15.

Cathcart type of teschenite, but especially to the bekinkinite modification of Barshaw and of many new Ayrshire localities. Still other masses show affinities to crinanitic types. Thus at New Gilston, Miss A. T. Neilson has collected a typical crinanite; whilst the Survey slide of the Drumcarrow Hill intrusion, 3 miles S.W. of St. Andrews, shows a rock of the same character, rich in fresh olivine and with fresh analcite in the interspaces between the felspars. A complete petrological survey of these Fifeshire intrusions is much to be desired (Ref. 15).

2. Analcite-Syenite—Crinanite—Kylite—Peridotite Sills of Ayrshire.

These may be roughly divided into three geographical groups: (a) the Dalmellington or Kyle assemblage, numerous large intrusions including the type kylite occurrence of Benbeoch; (b) a series of small masses occurring along the line of the valley of the River Ayr and including the type occurrences of analcite-syenite; (c) a series of large sills in the north central part of the county, stretching from Craigie, near Kilmarnock, to Troon. The Kyle sills are intrusive into Coal Measures. The Ayr Valley intrusives cut all members of the Carboniferous formation, and at least three in the Mauchline area cut the Permian lavas. The Craigie-Troon sills cut strata up to Coal Measures.

Carskeoch Hill provides the best evidence that both the teschenite and crinanite series are connected with late Carboniferous or Permian vulcanicity. The exposures indicate an agglomerate vent which is injected, along with the surrounding baked shales, by irregular sill-like intrusions of a very variable teschenitic rock rich in barkevikite. The most abundant type is akin to the bekinkinite differentiate of the teschenite series. This passes on the margins of the intrusions to a monchiquite which, in places, carries huge phenocrysts (or xenocrysts) of biotite, hornblende, and augite. The whole mass is again intruded by what appears to be a ring-dyke of a crinanitic rock (the Carskeoch "essexite"). Hence this occurrence shows the essential contemporaneity of the analcite rocks, amongst which the crinanites are probably slightly the younger, and their association with an undoubted Permian vent. The next vent to the west, Carclout, has an intrusion of porphyritic essexite, a characteristic member of the crinanite series (Ref. 8).

The petrography of the Mauchline lavas (Ref. 8), showing an abundance of basic, analcite- and nepheline-bearing basalts, is clearly in accord with the view that the teschenite and crinanite series represent the underground manifestations of the Permian igneous episode.

3. Crinanite-Kylite Sills of Arran and Bute.

The Triassic rocks of the south-eastern quarter of Arran are intruded by numerous basic sills, of which those of the Clauchland

Hills, Monamore Glen, King's Cross, and Dippin are the most important. For the most part these rocks are perfectly typical crinanites. A mafic modification, kylite, is sparingly present, but the analcite-syenite differentiate has not been found. Very coarse, even pegmatitic, patches are known (Clauchlands Point and King's Cross), and these tend to be richer in analcite than the dominant type.

These rocks must be post-Triassic, and can hardly be other than of Cainozoic age. The meagre evidence available [1] goes to show that they are among the earliest, if not the earliest, of the Cainozoic suite. They appear to avoid the great vent and large granitic areas of the island ; and there is good evidence that they constitute, in various modifications, the basic members of the composite sills and hybrid rocks, the mélanges of basalt and felsite, dolerite and granophyre, gabbro and granite, which occur so abundantly in the southern part of Arran.

In Bute the " Permo-Carboniferous " sill described by Dr. W. R. Smellie [2] is a typical crinanite identical in petrographical characters with those of Arran. It is intersected by a composite sill of hypersthene-dolerite and quartz-porphyry identical with that of Bennan Head in the south of Arran, and therefore almost certainly Cainozoic. Both intrusions cut the Lower Carboniferous lavas of South Bute.

4. Crinanite Dykes of the Mainland and Islands of the Clyde Estuary.

Of the many thousands of basic dykes which intersect rocks of all ages up to the Triassic along the shores of the Clyde Estuary, the larger ones frequently turn out to be crinanites of very much the same nature as those of the Arran sills. Some examples have been described in previous papers (Refs. 9, 13, 14), and many others have now been found.

The most frequent trend of these dykes is N.W.–S.E., and their average thickness is between 20 and 30 feet. Examples, however, are known of 40 and 60 feet (Inverkip, Renfrewshire), and 70 feet (Kildonan, Arran). The Inverkip dykes show exactly the same kind of felsic segregation veins and patches as some of the Arran sills.

Three of the dykes (Auchinweet Burn, Yonderton Burn, Failford) which intersect the Permian red sandstones overlying the Mauchline lavas are of crinanitic type, although their characters are somewhat obscured by alteration.

From the evidence of the Arran occurrences, which intersect Triassic rocks, this group of dykes is believed to be of Cainozoic age. They may, perhaps, represent the feeders of the crinanite sills.

5. Crinanite Dykes of the Western Coasts and Islands.

The type crinanite was first described by Dr. J. S. Flett as an example of a swarm of dykes whose centre lay near the Crinan

[1] Tyrrell, " The Petrography of Arran, III " : Geol. Mag., 1916, p. 196.
[2] " Igneous Rocks of Bute " : *Trans. Geol. Soc. Glasgow*, xv, pt. iii, 1916, p. 364.

Canal [1] (Refs. 6 and 7). They are associated with olivine-dolerites which differ from them only in the absence of analcite, and also with certain monchiquites and camptonites. These dykes have the characteristic N.W.–S.E. trend of the Cainozoic suite. They intrude rocks of ages ranging from the Lewisian of Lewis,[2] and the Dalradian of the western and south-western Highlands, to the Cainozoic lavas of Mull and Skye (Ref. 7). In a visit to western Skye in 1913 the writer found a dyke of quite typical crinanite cutting the Cainozoic basalt lavas near Idrigil Point, west of Uig. The lavas themselves at this locality are rich in interstitial zeolites, as has also been recorded for the lavas of other parts of Skye.[3] In another paper the writer has shown that there is chemical similarity between the crinanites and the Cainozoic basalts (Ref. 14, p. 361), and has raised the question as to whether the crinanite dykes are the hypabyssal representatives of the magma that gave rise to at least some of the basalts. On the Argyllshire mainland it has been shown that the crinanite dykes intersect the E.–W. quartz-dolerite dykes which are certainly not earlier than Permo-Carboniferous (Ref. 7, p. 41). The weight of evidence is therefore decidedly for the Cainozoic age of the crinanites and associated rocks in their type region of the western Highlands.

Conclusions.—The data as to age relations assembled in the foregoing contain nothing absolutely inconsistent with the idea of a Cainozoic age for the whole of the intrusive analcite-bearing igneous rocks of Scotland. Not even the priority of the teschenites to the quartz-dolerites at Inchcolm and elsewhere is inconsistent with this view, for the writer holds that the age of the last-named group is by no means proved to be Permo-Carboniferous. Certain facts, however, such as the petrographical affinities of the dated Mauchline lavas to the analcite-bearing rocks, their association with Permian vents, etc., make the hypothesis of Cainozoic age highly improbable. The weight of evidence makes it all but certain that the teschenite group, at any rate, is late-Carboniferous or Permian. There is somewhat less certainty regarding the age of the Ayrshire analcite-syenite—crinanite—kylite sills. As has been seen, some of these cut the Permian lavas. But their geographical association with the Permian lavas and vents of Ayrshire (and Fife ?), and the occurrence of crinanitic types within the vents, make their Permian age highly probable.

If the Permian age of the Ayrshire occurrences be thus accepted, we are then faced with the problem of the recurrence of practically identical rock-types in the Cainozoic, for the post-Triassic crinanite-kylite sills and dykes of Arran, Bute, and the Clyde Estuary can

[1] *Summ. Prog. Geol. Surv. for* 1909, 1910, p. 52.

[2] A. Stevens, "Geology of the Stornoway District of Lewis": *Trans. Geol. Soc. Glasgow*, xv, pt. i, 1913, pp. 51–63.

[3] A. Harker, "Some Aspects of Modern Petrology": *Rept. Brit. Assoc.*, 1911, p. 378.

hardly be other than of Cainozoic age. It has further been shown (p. 258) that the evidence is quite as strong, if not stronger, for the Cainozoic age of the crinanite dyke assemblage of the Western Highlands and Islands.

It is possible that a slight petrographical difference may be demonstrated between the Palaeozoic and the Cainozoic crinanites. So far as the evidence goes, the latter seem to be relatively poor in potash (cf. analysis of Jura crinanite with the crinanite of Howford Bridge and the kylite of Benbeoch, Table II). Also the analcite-syenite differentiate has not yet been found among the Cainozoic types, although the alkali-syenite of Carsaig Bay, Mull, approaches closely in chemical composition to that type.[1] The Cainozoic crinanites do carry numerous leucocratic veins and patches, but these always show dominant calcic plagioclase and are to be regarded merely as leucocratic varieties of crinanite or crinanite-aplite. More analyses, especially of the Arran sills, are urgently needed to clear up these and other points.

The intrusion of analcite-bearing rocks, therefore, appears to have ended the Palaeozoic cycle of eruption in the West of Scotland and to have begun the Cainozoic cycle. It seems probable that, as igneous activity died away in late Palaeozoic or early Mesozoic times, the magma basins which had supplied the crinanite sills were frozen solid. They thus remained quiescent during the long Mesozoic era of igneous inactivity; but on the inception of Cainozoic vulcanicity, they were the first foci to be reawakened. Thus it is possible to explain the geographical overlapping of the Palaeozoic and the Cainozoic analcitic igneous rocks, and the great development of the latter, especially in the Clyde region, within the sphere of influence of one of the largest Cainozoic magmatic centres, namely, Arran. In course of time some magmatic material (mostly acid) proper to the Cainozoic igneous episode worked upwards and mingled with the relic Palaeozoic magmas, producing the varied phenomena of composite dykes and sills, hybrid rocks, and acid-basic mélanges.

It is possible that the crinanite magma represents only a slight modification of the universal basaltic layer which is supposed immediately to underlie the crust and to have supplied the material for the great basalt floods of all ages.[2] It is significant that many of the most notable localities for zeolite minerals occur in the great plateau basalt regions and that these minerals are genetically associated with the basalts.

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[1] *Ann. Summ. Prog. Geol. Surv. for* 1912, 1913, p. 70.

[2] R. A. Daly, *Igneous Rocks and their Origin*, 1914, p. 164. H. S. Washington, "Deccan Traps and Other Plateau Basalts": *Bull. Geol. Soc. Amer.*, xxxiii, 1922, pp. 765–804.

(3) Mem. Geol. Surv. Scotland: *The Geology of East Lothian*, 1910, chaps. viii, ix, x.
(4) Mem. Geol. Surv. Scotland: *The Geology of Edinburgh*, 1910, chaps. xiv, xv.
(5) Mem. Geol. Surv. Scotland: *The Geology of the Glasgow District*, 1911, chap. iv.
(6) Mem. Geol. Surv. Scotland: *The Geology of Knapdale and Jura*, 1911, pp. 116–18
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On a Hitherto Unrecorded Intrusion from the Lleyn.

By Albert Heard, M.Sc., F.G.S., University College of South Wales and Monmouthshire.

During the last summer, whilst mapping the district between Nevin and Clynnog-fawr, I discovered the intrusion which is described in this communication. I can find no reference to it, either in geological maps of the Lleyn or in any geological literature, and conclude that the occurrence has not been placed on record.

The igneous rock outcrops about half a mile east of Llithfaen, north of the Tan-y-bwlch farm on the Nevin-Llithfaen road, and it is situate due east of the farm Ciliau-canol.[1] There are several good exposures on the western and northern margins where the boundary of the igneous rock is well marked. The eastern junction exhibits no fresh rock, but the uncultivated ground is covered with débris from the rock below, and presents no difficulty in mapping. Unfortunately, the southern margin is not so well marked, as the outbuildings, etc., of the Tan-y-bwlch farm have been built near the junction; but the igneous rock probably does not extend beyond the line indicated on the sketch-map (Fig. 1).

The outcrop of the Ciliau-canol intrusion is in the form of a lenticle with the major axis running approximately north-west–south-east. The rock is intrusive into arenaceous mudstones of Lower Ordovician age,[2] which have a dip of about 35° in a north-west

[1] See 6 in. top. map Carnarvonshire, Sheet xxxii, N.E.

[2] The exact horizon, etc., of these sediments will be discussed elsewhere in the near future: "The District between Nevin and Clynnog-fawr."

direction. The country rock along the south-western edge has been hardened, and in places has resisted weathering to a greater extent than the marginal igneous rock, consequently forming a small ridge.

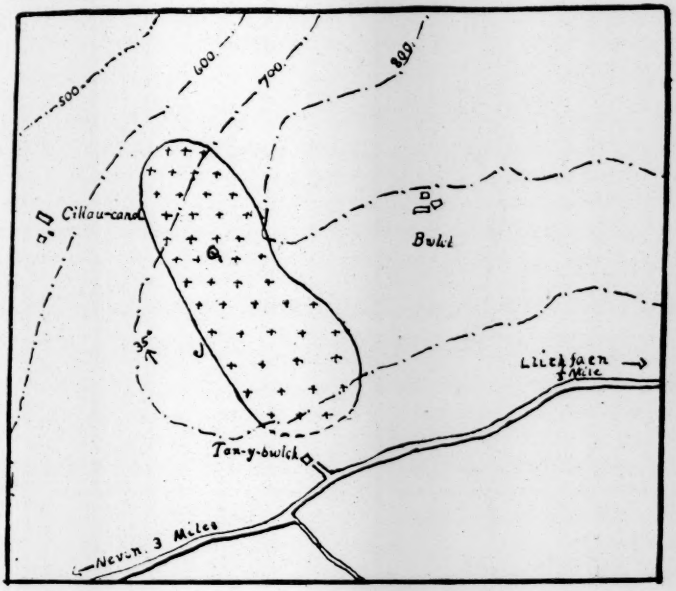


FIG. 1.—Map of the Ciliau-canol intrusion.

The freshest samples of igneous rock have been obtained from a small quarry (Fig. 1, Q), which presumably has been worked to supply building material for the neighbouring farms. The rock is well jointed, and exhibits considerable weathering along the joints. The normal rock presents a medium-grained leucocratic and spotted appearance, due to the dark idiomorphic hornblende crystals, which are surrounded by yellowish-brown and white

felspars with well-marked cleavage surfaces. Hornblende crystals 0·4 cm. long have been observed.

The actual junction of the igneous and sedimentary rocks is exposed at one place only (Fig. 1, J). The intrusive rock has been chilled, and forms a finely textured dark-grey rock, with an almost flinty appearance; minute phenocrysts of felspar and still smaller dark phenocrysts of ferro-magnesian minerals can be observed with the aid of a hand-lens.

The Normal Rock.

The normal rock has a typical granitic structure with a medium-grained texture, and under the microscope is seen to consist essentially of felspars, hornblende, and quartz, with iron ores, biotite, chlorite, etc. The quartz, which is fairly abundant, occurs as allotriomorphic grains filling up the interspaces between the other constituents. It calls for but little special description; its most interesting feature is the presence of an unusually large number of solid inclusions, which impart a cloudy appearance to many grains. In most cases these inclusions are scattered irregularly, and the characteristic "straight line" liquid inclusions are present only in a few occurrences. Amongst the solid inclusions apatite, amphibole needles, and rutile are abundant. The rutile inclusions frequently occur as relatively large, well-rounded foxy-red granules. The apatite and rutile inclusions are largely concentrated in the quartz areas, and are of rare occurrence in the felspars and ferro-magnesian constituents. Dr. J. V. Elsden[1] notes a parallel case in the St. David's Head rocks, where he describes the concentration of apatite in quartz areas, and suggests two possible explanations, viz. "either the separation of apatite was delayed by the presence of some substance which increased its solubility, or it was rejected by the pyroxenes owing to some peculiarity of surface tension, leading to capillary repulsion instead of attraction". As both rutile and apatite are concentrated in the quartz areas in the case of the Tany-bwlch intrusion, it is improbable that the first of Dr. Elsden's suggestions will account for their concentration. His second suggestion may possibly account for their presence in the quartz areas. At least two distinct types of *felspar* are present—plagioclase and weathered potash felspars. The *plagioclase felspars* occur in well-developed idiomorphic crystals. These felspars exhibit a well-marked zonal structure, with the more calcic type of plagioclase at the centre. Most of these crystals are fairly fresh, but their peripheries usually show great alteration. In a few cases, cross-hatching has been observed in fairly fresh portions of the outer edges of the zonal felspars; this suggests the presence of oligoclase-microcline. In composition the majority of the crystals range from a labradorite and andesine-labradorite at the centre to

[1] *Q.J.G.S.*, vol. lxiv, 1908, p. 289.

oligoclase-andesine, and in a few cases oligoclase towards the margin, followed by oligoclase-microcline, or possibly in some cases by microperthite. The potash felspars are relatively abundant, but are subordinate to the plagioclase felspars described above. *Microcline* is present in the rock in subhedral crystals. These crystals have turbid borders, and in most cases their crystallization has preceded that of the quartz. *Orthoclase felspar* occurs sparingly in turbid crystals with Carlsbad twinning, and has the usual dusty alteration products with sericite laths arranged along the cleavage planes. *Perthite* and *micro-perthite* are present in larger proportions than the orthoclase felspar. There are at least two distinct generations of felspars in the normal rock. The euhedral and subhedral forms of the zonal plagioclase felspars were probably crystallized before intrusion, whilst the potash felspars crystallized after intrusion and were moulded on the existing phenocrysts, in addition to their forming individual crystals. *Green hornblende* is the dominant ferro-magnesian mineral. It has a strong pleochroism (x—yellowish-green, y—yellow, z—greenish-brown) and a maximum extinction angle of 25°. The crystals are generally idiomorphic, as short or elongated prisms with the characteristic cross-section, and are associated with numerous granules of iron ores. *Rhombic pyroxenes* are not present in an unaltered form, but pseudomorphs of bastite, and still more frequently a colourless to pale-green, fibrous, highly birefringent amphibole, apparently after a rhombic pyroxene, suggest that originally rhombic pyroxenes were relatively abundant in the rock. These pseudomorphs are often present in the form of elongated prisms. *Biotite* is of rare occurrence, and is absent from some of the sections examined. *Apatite* occurs in the usual prismatic form, and invites no special description; it contains numerous small inclusions and occasionally long central cavities. *Iron ores*, both magnetite and ilmenite, are generally associated with the altered ferro-magnesian minerals. *Chlorite* is fairly common, mainly after amphibole, and generally occurs as irregular aggregates of small flakes. Occasionally a little granular sphene is associated with the chlorite. Small patches of chlorite are present also in the altered felspars. *Epidote* of secondary origin is present in the hornblende, plagioclase, and chlorite. A few slightly greenish-yellow euhedral crystals have been noted, which may possibly be pyrogenetic in the rock. These are faintly pleochroic (colourless to pale yellowish-green), and in one section of the rock a crystal of epidote has been noted which encloses a brownish core without any cleavage; this centre portion is in parallel orientation with the surrounding epidote and is presumably *allanite*.

The normal rock has an average specific gravity of 2·75, and a silica content of 60·3 per cent. Its potash-felspar content, although subordinate to that of the line felspars, is fairly high, and the rock is not far removed from the monzonite type. The rock is perhaps best described as a quartz-diorite.

The Marginal Rock.

Towards the boundary of the intrusion there is a marked increase in the basicity of the rock. A section, taken about 10 yards from the margin, shows, as compared with the normal rock, a larger proportion of zoned plagioclase felspars mainly labradorite to andesine—with a corresponding diminution of potash felspar. These plagioclase felspars are not rimmed with potash felspar, as are those of the normal rock. Interstitial primary quartz is present in relatively small amounts when compared with that occurring in the normal rock; but there is a marked increase in the amount of idiomorphic iron ore, and the apatite crystals are more numerous and larger. The ferro-magnesian minerals are represented mainly by chlorite, fibrous amphibole, and a little bastite.[1] A single small patch of micropegmatite was observed in this type; this is the only occurrence of micropegmatite which has been noted in any of the numerous thin sections from different parts of the Ciliau-canol intrusion.

Specimens taken about 1 foot from the margin show the character of the chilled edge. It is a porphyritic rock with phenocrysts of felspars and ferro-magnesian minerals in a fine-grained groundmass, consisting mainly of felspar, quartz, and rhombic pyroxene. *The felspar phenocrysts* consist entirely of plagioclase, which is mainly idiomorphic with a strong zonal structure. In composition, these phenocrysts generally range from oligoclase-andesine in the outer portion to labradorite in the centre. The border of potash felspar found round the zoned felspars of the quartz-diorite is absent from this chilled portion of the rock. Many of the phenocrysts show a corroded border, especially well marked in the case of the larger crystals, which have often become well rounded. A few smaller idiomorphic phenocrysts of a plagioclase felspar are present, and from their extinction angle are seen to be oligoclase-andesine. *Augite* occurs as allotriomorphic phenocrysts surrounded by intensely pleochroic biotite, which is present in rather indefinite patches with its associated chlorite and magnetite. The augite is colourless, and is remarkably free from inclusions. *Rhombic pyroxene* is present in the form of phenocrysts and also in a larger proportion in the groundmass. It consists of a variety poor in iron, as it is almost colourless in most of the crystals noted. A few crystals are slightly pleochroic (x—yellowish, y—yellowish, z—faintly greenish). Many crystals show a rather patchy alteration to bastite. The rhombic pyroxenes in the groundmass are mostly granular, though some crystals show idiomorphism. *Biotite*, in the form of irregular laths, is relatively abundant.

The groundmass consists of a finely crystalline aggregate of quartz, felspar, rhombic pyroxene, and iron ores. It is difficult

[1] I have been unable to obtain a fresh specimen of this type of rock.

to determine the exact nature of the felspars of which the groundmass is largely composed. The minute felspars show no trace of twinning, but have generally the peculiar extinction so characteristic of the cryptoperthite type. Occasionally larger crystals of oligoclase-andesine are present, and rarely some orthoclase showing Carlsbad twinning. The iron ores, apart from the large granules associated with the ferro-magnesian minerals, are generally in the form of minute perfect octohedra of magnetite. The most interesting features of this chilled type of rock are the great development of biotite and of monoclinic, and more especially of orthorhombic pyroxenes, and the absence of hornblende, which is only rarely present as inclusions in the plagioclase phenocrysts. The evidence of the plagioclase phenocrysts suggests that the rock was not entirely liquid on intrusion, for the crystals have been partially resorbed, presumably by the sudden increase in temperature caused by the latent heat liberated by the rapid crystallization.

The Invaded Sediments.

The invaded sediments, which consist of dark-grey mudstones, have been intensely thermo-metamorphosed by the igneous intrusion, and form a dark, hard hornfels. Under the microscope, the altered rock, at about 10 yards from the junction, exhibits a well-marked spotting, the spots consisting of ovoid spaces which are lighter in colour than the surrounding groundmass. The ovoid spaces consist of shimmer-aggregates of some strongly depolarizing micaceous material, which frequently appears to have a rough concentric arrangement. They probably represent either incipient or weathered cordierite crystals. The groundmass has a patchy pale-brown colour, due presumably to aggregated minute flakes of brown mica. Minute quartz crystals, both angular and rounded, can be observed. Opaque material, probably graphite and iron ores, is scattered abundantly throughout the rock, but practically all the larger fragments are confined to the groundmass. Andalusite occurs sparingly in the form of irregular granular aggregates. Nearer the junction, the ovoid spaces break down, and the altered cordierite forms a much larger proportion of the hornfels. The quartz crystals become larger, and minute blebs of quartz appear in the imperfect cordierite. Many of these quartz blebs and some of the opaque inclusions are surrounded by a yellowish-brown border, which is not a pleochroic halo. This yellowish-brown material may be *pinite*. The cordierite hornfels has lost almost all trace of clastic structure, and I have observed no schistose characteristics in the thin sections examined.

The Nature of the Intrusion.

The mudstones, into which the quartz-diorite is intruded, have a strike running approximately north-east–south-west (Fig. 1),

whilst the major axis of the lenticular outcrop of the Ciliau-canol intrusion is approximately at right angles to the direction of the strike. The igneous rock thus cuts across the bedding-planes of the sediments. This transgression across the strike suggests that the occurrence forms part of a stock; the quartz-diorite possibly representing the basic upper margin of a granite mass. This assumption is supported to a certain extent by the granitic structure of the rock and the almost total absence of micropegmatite, although even a granophyre laccolith generally has a granitic structure towards the outer edge.[1]

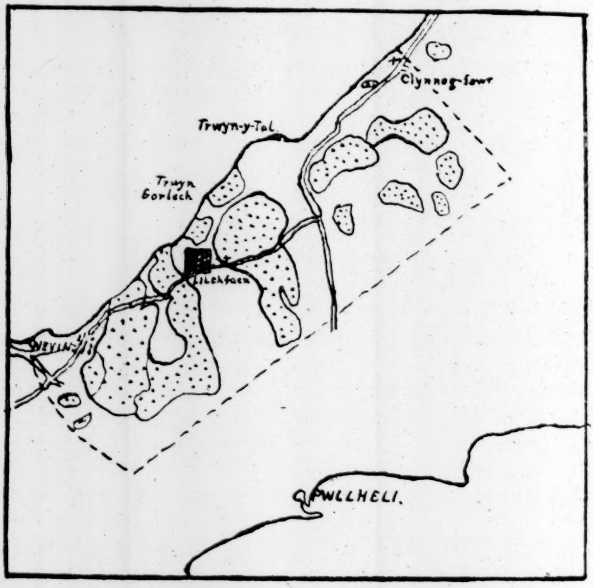


FIG. 2.—Sketch-map of the Nevin and Clynnog-fawr district, showing the relation of the Ciliau-canol intrusion to the other igneous rocks in the area. Scale, 1 inch = 4 miles. After ¼ in. map, *Geol. Surv. Eng. and Wales*, Sheet 9.

It is, however, possible that the Ciliau-canol intrusion represents the top of a tilted laccolith, or similar type of intrusion.

It is hoped that the detailed investigation of the neighbouring large igneous masses (Fig. 2) of the Nevin-Clynnog-fawr district, which is now in progress, will shed some further light on the petrographic relations of the Ciliau-canol intrusion.

[1] R. H. Rastall, *Q.J.G.S.*, vol. lxii, 1906, p. 253. A. Heard, GEOL. MAG., Vol. LIX, 1922, p. 359.

A New Fossiliferous Deposit in West Sussex.

By J. C. Ferguson, University College, London.

At the southern end of Thorney Island, about three miles S.S.W. of Emsworth, in West Sussex, there are low cliffs of London Clay covered by Pleistocene deposits. The London Clay has been folded near the top, and its surface presents a series of basin-like depressions, 3 to 10 feet in diameter, and evidently caused by downward pressure. These basins are occupied by Pleistocene gravel, which contains numerous erratics—many of igneous rocks—and resembles the better-known Erratic Gravel of Selsey. The Erratic Gravel is covered by Coombe Rock and Brickearth, which form the top of the cliff, as shown in the diagram.

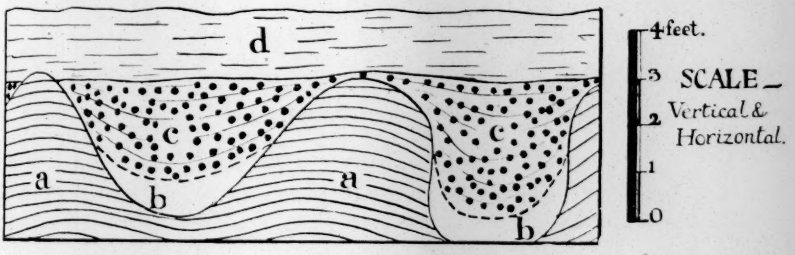


Fig. 1.—Diagram of cliff-section, Thorney Island. a, London Clay; b, green clay with fossils; c, erratic gravel; d, Coombe rock and brickearth.

As a rule, the Erratic Gravel rests directly on the London Clay, but, during the summer of 1922, the rapid erosion which the cliffs are undergoing revealed another deposit in about six of the basins, all adjacent ones. This new deposit comes between the London Clay and the Erratic Gravel; it is a green and yellow clay, with light calcareous patches, occupying the bottoms of the basins and spreading some way up their sides. This clay contains occasional small erratics and flints, and is full of shells, many of which are broken and worn. These fossils, for the identification of which I am indebted to Mr. C. P. Chatwin, are: *Ostrea edulis* Linn., variety, *Chlamys* (*Pecten*) *varius*, and *Trochus cinerarius*. The oysters are very abundant, and the Pectens fairly so, but only one specimen of the last-named fossil was found, despite careful search.

The boundary between the London Clay and this Green Clay-with-fossils is everywhere very distinct; in most places it is marked by a crack, along which the two deposits readily separate. On the other hand, there is no distinct boundary between the Green Clay and the Erratic Gravel, but the clay merges imperceptibly into the gravel.

The Riebeckite Granophyre of Ailsa Craig.

By Ashley G. Lowndes, M.A., F.G.S., Marlborough College.
(Late Head Microscopist, Nobel's Explosives Co., Ardeer.)

DURING the War a considerable amount of work of a somewhat geological nature was done in the laboratories of Nobel's Explosives Co., chiefly in connexion with providing acid-resisting material for use in the sulphuric and nitric acid plants.

This work involved the chemical analysis of many rocks both igneous and sedimentary, and included among others the famous riebeckite-granite or granophyre of Ailsa Craig.

The analysis was as follows:

SiO_2	69·40
Al_2O_3	15·73
Fe_2O_3	3·21
CaO	·21
MgO	·00
K_2O	5·76
Na_2O	4·75
	99·06

It has occurred to me that this analysis is of general interest and I am grateful to Mr. William Rintoul, F.I.C., Manager of Research of Nobel's Explosives Co., for permission to publish it.

New Fossils from Girvan.

By F. R. Cowper Reed, Sc.D.

(PLATE XII.)

Genus Cornulites Schlotheim.

SINCE the establishment of the two genera *Tentaculites* and *Cornulites* by Schlotheim in 1820 their relations have frequently been discussed, but no general agreement has been reached, and their characters have been differently defined by various authors, so that the generic position even of well-known species is rather an open question. For instance, the proper reference of "*Tentaculites*" *anglicus* Salter is still somewhat undecided.[1]

In connexion with British species one of the latest writers on the subject is Vine,[2] who in 1882 described certain forms from the Wenlock Shales, placing some of the species in one genus and some in the other. Both genera were referred by him to the tubicolous annelids, and he entered with some detail into the whole question of the separation of these genera, but without arriving at completely satisfactory conclusions. To a great extent he adopted Nicholson's[3]

[1] Vine, *Quart. Journ. Geol. Soc.*, vol. xxxviii, 1882, pp. 379, 387; Foerste, *Proc. Boston Soc. Nat. Hist.*, vol. xxiv, 1889, p. 276.

[2] Vine, op. cit., pp. 377–92, pl. xv.

[3] Nicholson, *Amer. Journ. Sc.*, ser. III, vol. iii, 1872, p. 202.

earlier views, but he gave amended definitions of the genera as follows :—

Cornulites.—" Tube annulated, striated longitudinally, attached by some portion of its extremity to foreign bodies." Further on he stated that the animal is solitary, inhabiting a tube of carbonate of lime which has " very thick walls composed of numerous imbricating conoidal rings, their widest end next the slender base and subirregular in old specimens, more or less distorted or oblique in the young ; external surface obscurely annulated, finely striated longitudinally ; inner surface and casts scalariform, with two or three longitudinal furrows ".

Tentaculites.—" Tube annulated, devoid of longitudinal striæ or of cellular structure, conical, straight, tapering towards one extremity and wholly unattached to any foreign body." Nicholson (op. cit., p. 206) specially remarks that the shell is thin. On the other hand Barrande [1] stated that in most species of *Tentaculites* longitudinal striæ are present, and he also observed that in certain cases the internal casts do not agree with the outer surface of the test and simulate the appearance of *Cornulites*. Hall,[2] moreover, had described in 1859 an internal cast of *Tentaculites elongatus* which possessed the imbricating segmental rings of *Cornulites* to which Barrande alludes. The internal structure of *T. annulatus* Schlotheim [3] from the Silurian of Gotland, which is the type species of the genus *Tentaculites* Schlotheim, does not appear to have been ever investigated or described, and we may doubt if the thin-shelled closely annulated forms, such as *T. elegans* Barrande [4] of the Lower Devonian of Bohemia, belong to the same genus as the thick-shelled Silurian species.

Most species of *Tentaculites* are described as straight, and all of them as free and unattached, but some shells which have been referred to this genus are curved, e.g. *T. curvatus* Boll [5] and *T. incurvus* Shumard,[6] though the last-mentioned species has been referred by Hall [7] and Savage [8] to *Cornulites*.

The type species of *Cornulites* Schlotheim is *C. serpularius* Schlotheim [9] ; this is annulated, curved, more or less twisted, and attached, and it occurs usually in groups of two or more individuals. In 1864 Ludwig [10] defined the genus in the following manner : Shell small, with transverse section circular, closed at base [= apex],

[1] Barrande, *Syst. Silur. Bohême*, vol. iii, pp. 110–34.
[2] Hall, *Palæont. New York*, iii, 1859, p. 136, pl. vi, figs. 16–21.
[3] Schlotheim, *Petrefact.*, 1820, p. 377, pl. xxix, fig. 8*a* (*non* 8*b*) ; Moberg & Grönwall, *Kungl. Fysiogr. Sällsk. Handl.*, Bd. 20, No. 1, 1909, p. 46, t. ii, fig. 1.
[4] Barrande, op. cit., p. 131, pl. xiv, figs. 20–7.
[5] Boll, *Zeitschr. deut. Geol. Gesell.*, Bd. viii, 1856, p. 321.
[6] Swallow, *Second Ann. Rept. Geol. Surv. Missouri*, 1855, p. 195, pl. B, fig. 6.
[7] Hall, *Palæont. New York*, vol. vii, Suppl., 1888, p. 18, pl. cxv, fig. 31 ; pl. cxvi, fig. 31.
[8] Savage, *Bull.* 23, *Geol. Surv. Illinois*, 1913, p. 41, pl. ii, fig. 7.
[9] Schlotheim, op. cit., p. 378, pl. xxix, fig. 7.
[10] Ludwig, *Palæontographica*, xi, 1864, p. 317, t. l, fig. 4.

having closed annulations, without longitudinal slit or operculum. The test is composed of imbricating hollow cones of which the larger aperture is directed towards the base and which fit into one another. The internal cast appears to be composed of a series of steps or segments and is not smooth. Ludwig's specimens came from the Devonian, but Schlotheim's type, as stated above, came from the Silurian of Gotland. Barrande (op. cit., pp. 167–74) quotes this definition and apparently adopts it. But it does not agree with that given by Vine. Ludwig figured as an example of *Cornulites* a shell from the Devonian to which he applied the name *C. scalaris* (Schloth.), although Schlotheim put this species in his genus *Tentaculites*; the figure shows a straight shell, with the internal cast composed of imbricating conical rings corresponding with the annulations on the surface.

Hall (op. cit., 1888, pp. 8–24) discussed the general structure of *Cornulites*, particularly the minute internal structure of the shell itself, and believed that in the early stages the tube was smooth, the annulations being developed later, but becoming obsolete with the growth of the animal; and that the longitudinal striæ which are at first obscure persist after the annulations are lost. In the early stage he stated that the organism is attached and parasitic, but in an advanced state of growth it is free and unattached. The present author is not, however, prepared to adopt Hall's views in their entirety, particularly in regarding *Ortonia* and *Conchicolites* as synonyms for *Cornulites*.

Nicholson [1] in 1890 introduced some modifications of his earlier views of the characters of *Tentaculites*, stating that the internal cavity is sometimes crossed by transverse partitions and that longitudinal as well as encircling striæ are occasionally present. But he maintained that the shell was invariably free and that the microscopic structure of the tube was totally unlike that of *Cornulites*.

Grabau [2] in 1899 gave a fresh definition of *Tentaculites* as follows: "Shell straight, elongate attenuately conical tubes, their surfaces marked by strong rings or annulations which are closely arranged near the apex and more distant and stronger near the mouth. Fine transverse and rarely longitudinal striæ are present." The same author in 1901 [3] defined *Cornulites* as follows: "Tube gently tapering, flexuous, the small end usually bent. The tube is either wholly or in part adherent to other objects. Walls thick, cellular, composed of imbricating rings. Surface ornamented by annulations and longitudinal striæ. Interior presenting a succession of annular constrictions giving a scalariform character to the cast."

Clarke & Ruedemann [4] in their figures of the internal cast of

[1] Nicholson, *Trans. Edinburgh Geol. Soc.*, vol. vi, 1890, pp. 66, 67.
[2] Grabau, *Bull. Buffalo Soc. Nat. Sc.*, vol. vi, 1899, p. 282.
[3] Ibid., vol. vii, 1901, p. 161.
[4] Clarke & Ruedemann, *Mem. New York State Mus.*, N.S., 1903, p. 105, pl. iv, figs. 1–5.

C. arcuatus Conr. from the Guelph Limestone clearly showed the imbricating nature of the successive segments of the internal cast, but in this case there are no corresponding annulations on the exterior.

Many of the American shells originally referred to *Tentaculites* are now placed in the genus *Cornulites*, and reference to some of them is made below.

The specimens from Girvan which have been put into my hands by Mrs. Gray combine some of the characters found in *Tentaculites* with others of *Cornulites* as defined by Vine, for the shells are free and unattached as in the former, but have the longitudinal striæ or lines on the test and the imbricating segmental structure which are said to mark *Cornulites*; they are also mostly more or less curved, which is unknown or unusual in true *Tentaculites*. A careful examination of the exterior of the shell of all the species described below shows that the annulations are really caused by a thickening of the lower or overlapping edge of each segment, and in a natural longitudinal section of the shell these annulations are thus seen to be not symmetrical rings even externally in cross section, the concave curve of their surface being long and gradual on the upper side, but steep and short on the lower side so as to make nearly a right angle with the surface of the next lower segment towards the apex. This imbricating segmental structure is much more clearly visible in internal casts, but it is obvious in both cases that the annulation is only marginal and belongs solely to the upper and overlapping segment.

The segmented nature of these shells appears sufficient to place them definitely as members of the *Annelida tubicola* and to separate them from the *Pteropoda*.

The question of the generic position of the other British species of "*Tentaculites*" cannot be discussed here.

The specimens which are descibed in the present paper have been collected at Girvan from time to time by Mrs. Gray, of Edinburgh; most of them are now in the British Museum and the reference numbers are given in parentheses. A few additional specimens which were found by Mrs. Gray in 1921–2 have also been examined by me, and some are figured.

Cornulites girvanensis sp. nov. (Plate XII, Figs. 1–3.)

Shell elongated, subcylindrical, gently curved, tapering very slowly at about 1 in 12 in the upper two-thirds of its length and then rather more rapidly and with stronger curvature to apex, composed of 20–35 segments, and marked by strong concentric annulations of which those on the upper two-thirds are set at fairly regular distances apart, equal to about half or two-thirds or nearly the whole diameter, while those in the apical third of the shell are more closely crowded. Segments short, slightly conical, forming imbricating rings successively overlapping each other from above, each having a gently

concave surface, with the lower edge of the segment swollen and rising rather suddenly into a prominent subangular marginal annulation which is more or less abruptly truncated below and descends steeply to next segment; each segment is ornamented with 4-6 narrow low faint concentric rings, frequently indistinct, and the whole shell is covered with regular equidistant fine thread-like raised longitudinal lines of rather unequal strength crossing the interspaces and annulations without interruption. A few faint low broad concentric lines are usually visible in each interspace.

Dimensions.	I	II
Length on curve	26·5 mm.	*c.* 38 mm.
Diameter at mouth	3·5 mm.	4 mm.
Number of annulations in upper two-thirds of shell	14	18
Ditto in apical third	11	*c.* 16

Horizon.—Saugh Hill Group (Middle Llandovery).

Locality.—Woodland Point (A. 2451 to 2462, A. 2506 to 2508).

Remarks.—This species is represented by several fairly perfect specimens showing the structure and external ornamentation of the shell. The segmental nature is recognized even on the surface of the test by the relation and section of the annulations, the difference in the slope of their upper and lower surfaces being clearly seen on a careful examination of the exterior. The species is much like the so-called *Tentaculites anglicus* Salter in its ornamentation and annulations. Vine (op. cit., p. 379) suspected that some, at any rate, of the shells usually referred to the latter species should be placed in *Cornulites* and remarked on its resemblance in many ways to his *C. scalariformis*[1] of the Wenlock Shales. But the curvature of our Girvan shell is distinctive, and in this feature as well as in the crowding of the annulations towards the apex it bears a likeness to *Cornulites incurvus* (Shumard)[2] of the Girardeau Limestone (Upper Medinan) of Missouri as described by Hall, Keyes, and Savage,[3] and also to our new species *C. shallochensis* (see below).

Cornulites camreganensis sp. nov. (Plate XII, Figs. 4, 5, 5*a*.)

Shell elongated conical, straight or very slightly curved, tapering about 1 in 5 or 6, composed of numerous segments of equal or subequal length. Annulations narrow, subangular, moderately prominent, set at equal or subequal distances apart (i.e. about half the diameter) for nearly the whole length of shell, becoming rather more closely placed near apex. Interspaces gently concave, each with 2–6 strong distinct concentric narrow granulated lines. Whole

[1] Vine, *Quart. Journ. Geol. Soc.*, vol. xxxviii, 1882, p. 379, pl. xv, figs. 1, 9, 10.

[2] Swallow, *Second Ann. Rept. Geol. Surv. Missouri*, 1855, p. 195, pl. B, figs. 6*a–b*.

[3] Hall, *Palæont. New York*, vol. vii, Suppl., 1888, p. 18, pl. cxv, fig. 31; pl. cxvi, fig. 31; Keyes, *Missouri Geol. Surv.*, vol. v, pt. ii, 1894, p. 217, pl. xxxv, fig. 3; Savage, *Bull. 23, Geol. Surv. Illinois*, 1917, p. 97, pl. iv, fig. 7.

shell covered with faint longitudinal striæ, much weaker and finer than the concentric markings. In internal casts the segments are seen to be composed of imbricating rings of equal or subequal length with slightly swollen rounded lower edges corresponding to the annulations on the surface.

Dimensions.—Length, 10·5 mm. Diameter at mouth, *c.* 2·0 mm.

Horizon.—Camregan Group (Upper Llandovery).

Locality.—Camregan Wood (A. 2509 to 2511, A. 2473 to 2477).

Remarks.—This species has a much more conical shape and tapers more rapidly than *C. vinei* sp. nov. from Newlands (see below), and it has the annulations set at more equal and wider distances apart. The strong concentric granulated lines in the interspaces and the weakness of the longitudinal lines, which can only be indistinctly detected even with a lens, are further points of difference.

Cornulites mullochensis sp. nov. (Plate XII, Figs. 6, 6*a*, 7.)

Shell very slender, conical, slightly curved near apex, tapering in upper four-fifths at about 1 in 15, composed of very numerous segments. Annulations prominent, subangular, close and regularly equidistant in upper half of shell, being about one-third to one-fourth the diameter apart, but becoming further apart in lower half so as to be separated by interspaces from one-half to two-thirds the diameter. Interspaces strongly concave. Whole shell marked with strong raised longitudinal lines crossing the annulations and interspaces alike. In internal casts the segments show as imbricating nearly flat rings with very slightly swollen lower margins and are short and of equal length in the upper half, but become considerably longer towards the apex.

Dimensions.—Length, *c.* 14·0 mm. Diameter at mouth, *c.* 2·0 mm. Number of annulations, 30–40.

Horizon.—Mulloch Hill Group (Lower Llandovery).

Locality.—Mulloch Hill (A. 2512 to 2519, A. 2467 to 2472).

Remarks.—This species is distinguished by its slender form and by the close annulations and short segments in its upper half instead of in its lower portion as in *C. girvanensis*. The curvature of the shell is also much less marked and the longitudinal lineation is coarser than in that species. Owing to the thickness of the shell in *C. mullochensis* the external annulations seem to be rather lower (i.e. more apical) than the swellings along the base of the segments of the internal casts, as is seen in Figs. 6*a*. The same feature is conspicuous in *C. vinei* from Newlands (see below).

Cornulites shallochensis sp. nov. (Plate XII, Figs. 8, 8*a*.)

Shell elongated conical, gently curved, tapering slowly at about 1 in 6 or 7 towards apex. Segments short, marked by strong prominent angular or subangular annulations, of which those in the upper three-fourths of the shell are set at one-third to one-half the diameter apart at fairly regular intervals, but those nearer the

apex are more crowded together and the interspaces are consequently narrower. Interspaces concave, marked with very delicate fine longitudinal striations which seem to be continuous from segment to segment and to cross the annulations (which bear granules?) uninterruptedly.

Dimensions.—Length along curve, *c.* 18·0 mm. Diameter of mouth, 3·75 mm. Number of annulations, 22–24.

Horizon.—Whitehouse Group (Middle Bala).

Locality.—Shalloch Mill (A. 2482).

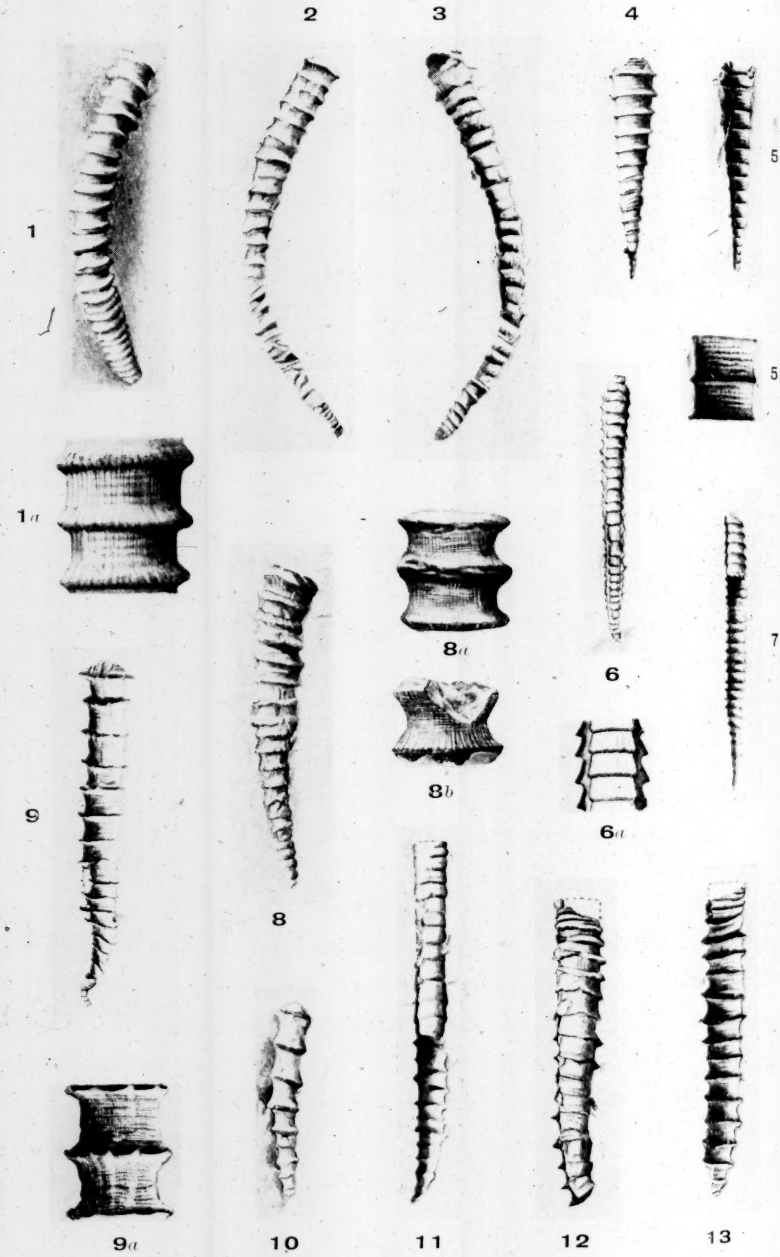
Remarks.—Only one good specimen of this species is known to me, and the last few rings of the apex of it are missing. Several fragments also occur in Mrs. Gray's recent collection. It differs from *C. girvanensis* in its more rapid tapering, the greater approximation of the annulations, and the much finer longitudinal ornamentation. Whether concentric lines are present or not is doubtful, but there are indications that the crest of the annulations bears granulations. The nature of the annulations and interspaces and their relations to the segments is as clearly visible in this species as in *C. girvanensis*. With regard to its further affinities we may specially mention *C. richmondensis* (Miller) from the "Hudson River Group" of Indiana.[1] Perhaps *C. tenuistriatus* (Meek & Worthen),[2] of the Cincinnati Group, is also allied.

Cornulites vinei sp. nov. (Plate XII, Figs. 9–13.)

Shell very slender and elongated, straight or gently curved near apex with occasionally a double bend at apex, subcylindrical for the greater part of its length but finally tapering slowly to apex; composed of numerous segments of equal or subequal length. Shell much thickened at annulations which are prominent angular or subangular, and smooth except for occasional swellings or wide crenulations of the crest; annulations set at fairly regular and equal distances apart, varying from half to two-thirds the diameter, but usually set much closer together near mouth. Interspaces strongly concave, ornamented with a few thicker concentric lines and more numerous very fine minutely granulated concentric striæ; a very delicate longitudinal striation is rarely visible. In internal casts the imbricating segments are mostly of regular size and cylindrical, with scarcely thickened basal edge, and have a length equal to or greater than the diameter owing to the thickness of the shell; the annulations on the external surface of the shell usually come below (i.e. nearer the apex) the basal edges of the segmental casts, particularly in the case of the middle and apical portions of the shell, thus causing an apparent non-correspondence of the segments and rings.

[1] Hall, op. cit., p. 18, pl. cxv, figs. 28–30, 33–9, and references in Bassler, *Bull.* 92, *U.S. Nat. Mus.*, vol. i, 1915, p. 280.

[2] Savage, *Bull.* 23, *Geol. Surv. Illinois*, 1917, p. 97, pl. iv, fig. 6.



T. A. Brock del.

CORNULITES FROM GIRVAN.

To face p. 255.]

Dimensions.—Length, *c.* 18·0 mm. Diameter at mouth, *c.* 1·5 mm. Number of segments in specimen, *c.* 30.

Horizon.—Saugh Hill Group (Middle Llandovery).

Locality.—Newlands (A. 2500 to 2505; A. 2463 to 2466; A. 2490 to 2499 Brit. Mus.; and Mrs. Gray's coll.).

Remarks.—Most of the specimens are imperfect or broken, but many have counterparts, and show the internal cast attached to part of the length of the hollow impression of the exterior, so that the reason for the apparent non-correspondence of the rings and segments is explained. The occasional sigmoidal curvature of the apex is remarkable. There is a close resemblance between this species and *C. mullochensis*, but the nodular ornamentation of the rings and the lineation of the interspaces are distinctive characters.

Cornulites sp.

One broken specimen of the upper part of the shell of some species of *Cornulites* is the only representative of the genus known to me from Penkill. It is rather a large form and tapers rather rapidly; a slight curvature is noticeable and the annulations which are low, broad, and subangular are set at rather unequal distances apart and seem to be rather oblique to the axis in one or two cases. The length of the fragmentary shell is 11 mm. and it possesses 7–8 segments; the diameter at the mouth is just 4 mm. and the rate of tapering is about 1 in 5. But no sufficient specific characters are present, though it seems separable from those above described.

Horizon.—Penkill Group (Tarannon).

Locality.—Penkill (A. 2488).

EXPLANATION OF PLATE XII.

FIG.

1.—*Cornulites girvanensis* sp. nov. × 2. Saugh Hill Group, Woodland Point, Girvan. (A. 2461, Brit. Mus.)

1*a*.—Ditto. Two segments of same specimen. ×6.

2.—Ditto. × 1½. Same horizon and locality. Mrs. Gray's Coll.

3.—Ditto. Impression of same specimen. × 1½. Mrs. Gray's Coll.

4.—*Cornulites camreganensis* sp. nov. × 3. Camregan Group, Camregan Wood, Girvan. (A. 2473, Brit. Mus.)

5.—Ditto. Impression of exterior. × 3. Same horizon and locality. (A. 2476, Brit. Mus.)

5*a*.—Ditto. Two segments of same specimen. × 6.

6.—*Cornulites mullochensis* sp. nov. × 3. Mulloch Hill Group, Mulloch Hill, Girvan. (A. 2468, Brit. Mus.)

6*a*.—Ditto. Internal cast of some segments of same specimen showing thickness of shell. × 6.

7.—Ditto. Impression of part of exterior with internal cast of upper segments. × 3. Same horizon and locality. (A. 2469, Brit. Mus.)

8.—*Cornulites shallochensis* sp. nov. × 2½. Whitehouse Group, Shalloch Hill, Girvan. (A. 2482, Brit. Mus.)

8*a*.—Ditto. Two segments of same specimen. × 6.

8*b*.—Ditto. Another segment of same specimen. × 6.

9.—*Cornulites vinei* sp. nov. Impression of exterior. × 3. Saugh Hill Group, Newlands, Girvan. (A. 2494, Brit. Mus.)

9*a*.—Ditto. Two segments of same specimen. × 6.
10.—Ditto. Apical portion of shell. × 3. Same horizon and locality. Mrs. Gray's Coll.
11.—Ditto. Shell showing part as internal cast and part as external impression. × 3. Same horizon and locality. (A. 2464, Brit. Mus.)
12.—Ditto. Upper (oral) part of another specimen, showing internal cast. × 3. Same horizon and locality. Mrs. Gray's Coll.
13.—Ditto. External impression of same specimen. × 3. Mrs. Gray's Coll.

The Base of the Devonian, with special reference to the Welsh Borderland.

By L. Dudley Stamp, B.A., D.Sc., A.K.C., F.G.S.

Contents.

I. Introduction.
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III. Historical Summary of the Siluro-Devonian Junction Controversy.
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V. Palæontology of the Downtonian of the Welsh Borderland.
VI. Comparison with Other Regions.
VII. Probable Palæogeography of Lower Devonian Times.
VIII. Conclusion and Summary.

I. Introduction.

In 1916 the writer carried out a field survey of a district in Shropshire in which the "passage beds" between the Silurian and "Old Red Sandstone" are well developed. So apparent was the difficulty of drawing a dividing line between the two systems that a description of the district was published without a decision being reached.[1] Shortly afterwards active service in France and Belgium brought opportunities of studying both field and museum evidence there. The writer came to conclusions which he afterwards found agreed very closely with those reached shortly before by MM. Barrois, Pruvost, and Dubois, who had approached the problem from a different standpoint.[2] A preliminary summary was published[3] and in 1920 the Council of the Geological Society awarded the author the "Daniel Pidgeon Fund" for the purpose of enabling him to carry out a comparative study of the Downtonian and Gedinnian. The results were laid before the Society in November, 1921.[4] The Council have, however, declined to publish the paper, though their decision in this matter was not communicated to the author until nine months after the reading of the paper. A short

[1] Stamp, "The Highest Silurian Rocks of the Clun Forest District, Shropshire": *Quart. Journ. Geol. Soc.*, vol. lxxiv, 1918, pp. 221–44.

[2] Barrois, Pruvost, & Dubois, "Sur les couches de passage du Silurien au Dévonien dans le Bassin houiller du Pas-de-Calais": *C.R. Acad. Sci.*, vol. clxvii, 1918, p. 705.

[3] Stamp, "Note on the Determination of the Limit between the Silurian and Devonian Systems": Geol. Mag., Vol. LVII, 1920, p. 57.

[4] Stamp, "The Base of the Devonian, with especial reference to the Welsh Borderland": *Abs. Proc. Geol. Soc.*, No. 1075, November 19th, 1921, p. 6.

summary of the results obtained (but not of the field evidence) has been published in Belgium.[1] The main object of the present note is to place on record the field-work on which the general conclusions are based. One of the principal objections to the writer's conclusions which was raised when the paper was read before the Geological Society was that "the question where the line between the Silurian and the Devonian was to be drawn should be primarily determined in areas in which normal marine conditions had prevailed, not in one of exceptional character, like the Welsh Borderland".[2] This objection has now been removed by the publication of the Memoir on the Siluro-Devonian Faunas of Liévin.[3] Through the courtesy of the authors, the proofs of this work had been previously communicated to the writer. It will be seen in the sequel that the results of both lines of investigation have proved to be identical.

II. The Suggested Classification of the Siluro-Devonian Rocks of the Welsh Borderland.

The classification suggested for the Silurian and Lower Devonian rocks of the Welsh Borderland is as follows :—

Lower Devonian (O. R. S. Facies)	II. Dittonian.		
	I. Downtonian	"Red Downtonian" including the fish-beds of Trimpley and Ledbury.	
		Temeside Shales.	
		Downton Sandstone with *Platyschisma* Shales.	
		Ludlow Bone-bed.	
Silurian	III. Ludlovian	Upper Ludlow Group.	
		Aymestry Group.	
		Lower Ludlow Group.	
	II. Wenlockian.		
	I. Valentian.		

VALENTIAN (Lapworth, 1876). This term is used in its original or usual sense as recently defined by Professor O. T. Jones.[4]

WENLOCKIAN. Used in the same sense as the Wenlock Series of Murchison (1834) or as defined with reference to the graptolite faunas by Miss G. L. Elles.[5]

LUDLOVIAN. This term is used to embrace the same rocks as the original Ludlow Series of Murchison (1834), with the exception

[1] Stamp, "La base du système dévonien en Angleterre": *Bull. Soc. belge Géol.*, vol. xxxi. 1921, pp. 87–98.

[2] *Abs. Proc. Geol. Soc.*, No. 1075, 19th November, 1921, p. 8.

[3] Barrois, Pruvost, & Dubois, "Description de la Faune siluro-dévonienne de Liévin": *Mém. Soc. Géol. Nord.*, vol. vi (II), pt. ii, 1920 (1922); see review in Geol. Mag., Vol. LX, 1923, p. 92.

[4] Jones, "The Valentian Series": *Q.J.G.S.*, vol. lxxvii, 1921, p. 144.

[5] Elles, "The Zonal Classification of the Wenlock Shales of the Welsh Borderland": ibid., vol. lvi, 1900, p. 370.

that the Ludlow Bone-bed is removed to the Downtonian. It thus includes the rocks from the Lower Ludlow Shales to the Upper *Chonetes* Beds (*Spirifer elevata* Shales of Elles & Slater[1]) inclusive. The Ludlovian is divisible into three groups :—

(i) Lower Ludlow Group—graptolitic shales described by Miss E. M. R. Wood (Dame Ethel Shakespear).[2]

(ii) Aymestry Group—defined by Miss Elles and Miss Slater,[1] comprising the *Dayia* Shales and Aymestry Limestone.

(iii) Upper Ludlow Group—used as defined by Elles & Slater, except that the Ludlow Bone-bed, placed by them at the top, is considered as forming the base of the succeeding Downtonian. The group comprises :—

(*b*) *Chonetes* Beds .	Upper or *Spirifer elevata* Shales.
	Lower.
(*a*) *Rhynchonella* Beds.	

Details of these beds will be found in Elles & Slater's paper and in the writer's former paper.[3]

DOWNTONIAN (Lapworth, 1880, redefined by the Geological Survey of Scotland,[4] and applied to the Scottish succession in 1899; used with the same definition and applied to the English succession by Stamp in 1920[5]). The Downtonian may be briefly defined as the beds between the Ludlovian and the Dittonian or Lower Old Red Sandstone with the *Pteraspis-Cephalaspis lyelli* fauna. In a positive sense the Downtonian is the lowest division of the Devonian (Old Red Sandstone facies) and is characterized by the first appearance of a large number of genera and species of fish. If they occur at all, it is only very rarely that fish-remains are found in Pre-Devonian rocks. The commencement of the Devonian corresponds then with the dawn of an era of vertebrates. As contrasted with later series, the Downtonian is characterized by the abundance of Anaspidæ, Palæaspidæ, and simple Cephalaspidæ, and the absence of Pteraspidæ. The lower part of the Downtonian of the Welsh Borderland comprises a complex of shales, sandstones, and greenish rubbly shales (the Temeside Group of Elles & Slater). The thickness of this lower group rarely exceeds 500 feet. The upper part comprises a mass of red and green marls and sandstones with cornstone bands, which has only recently been separated from the Dittonian or Lower Old Red Sandstone with a *Pteraspis* fauna. The entire credit of the discovery of the great extent and thickness (probably never less than 1,500 feet in the central region

[1] Elles & Slater, "The Highest Silurian Rocks of the Ludlow District": ibid., vol. lxii, 1906, p. 195.

[2] Wood, "The Lower Ludlow Shales of the Welsh Borderland": ibid., vol. lvi, 1900, p. 415.

[3] Stamp, "The Highest Silurian Rocks of the Clun Forest District": ibid., vol. lxxiv, 1918, p. 221.

[4] Peach & Horne, "The Silurian Rocks of Britain: Vol. I, Scotland": *Mem. Geol. Surv.*, 1899.

[5] Stamp, op. cit., 1920.

of Shropshire) is due to Mr. W. Wickham King. The author is greatly indebted to Mr. King for permission to incorporate here some of his results, as yet unpublished. The present paper is restricted to a detailed study of the lower part of the Downtonian.

DITTONIAN (W. W. King, 1921). This name has been proposed to embrace the remainder of the Lower Old Red Sandstone of the Welsh Borderland, after the removal of the lower 2,000 feet or more, which has now been shown by its fish fauna to be of Downtonian age. The Dittonian is named from Ditton Priors, Shropshire, and is characterized by the presence of *Pteraspis rostrata, Pteraspis crouchii, and Cephalaspis lyelli.*

III. Historical Summary of the Siluro-Devonian Junction Controversy.

Having now outlined the classification used in this paper, some details may be added concerning previous attempts to define the limit between the Silurian and Devonian Systems. Murchison originally fixed the lower limit of the Old Red Sandstone below the Downton Castle Sandstone, i.e. at the horizon of the Ludlow Bone-bed.[1] The term "Silurian" was actually proposed for the first time by Murchison in 1835 to include "a complete succession of fossiliferous strata interpolated between the Old Red Sandstone and the oldest slaty rocks".[2] He had in the previous year, however, already divided that series into four groups—Ludlow Rocks, Wenlock and Dudley Rocks, Horderley and May Hill Rocks, and Builth and Llandeilo Flags.[3] At the time of the introduction of the term "Silurian" the Old Red Sandstone itself was divided into three groups[4]:—

(*c*) Conglomerates and Sandstones.
(*b*) Cornstones and marl.
(*c*) Tilestones, including the Downton Castle Building Stone.

The discovery of brachiopods and other Ludlovian fossils in the Tilestones led Murchison somewhat later (1848) to include these beds in the Silurian. Nevertheless, he long continued to regard the Tilestones as naturally forming part of the Old Red Sandstone, or as beds capable of being grouped with either the Silurian or the Old Red Sandstone. In the "Silurian System" (1838–9) even the Fish-bed and the Fucoid-bed are regarded as belonging to the "upper beds forming the downward passage from the Old Red System". In the later editions of Siluria the "highest member of the Ludlow rocks" is the Ludlow Bone-bed,[5] whilst the Tilestones are the "uppermost layers of the whole Silurian System and which form a transition into the Old Red Sandstone".[6]

[1] *London and Edinburgh Philosophical Magazine*, N.S., vol. vii, pp. 45–52.
[2] *Silurian System*, 1839, p. 7.
[3] *Proc. Geol. Soc.*, vol. ii, pp. 9–13 (8th January, 1834).
[4] Op. jam. cit., 1834.
[5] *Siluria*, 4th edition, 1867, p. 133.
[6] Ibid., p. 134.

TABLE SHOWING THE DIFFERENT CLASSIFICATIONS OF THE SILURO-DEVONIAN BEDS OF SHROPSHIRE.

Murchison 1834–5. (1)	Murchison, 1848–67. (2)	Phillips, 1848. (3)	Page, 1856–76. (4)	Prestwich, 1887. (5)	Elles and Slater, 1906. (6)	King and Lewis, 1917. (7)	Stamp, 1918. (8)	Barrois, Pruvost, Dubois, 1918–22. (9)	Stamp, 1920. (10)	Stamp, 1921–2. (11)	
						L.O.R.S.	? L.O.R.S.	L.O.R.S.	L.O.R.S.	Dittonian.	
Lower Old Red Sandstone Marls	L.O.R.S.	L.O.R.S.	L.O.R.S.	L.O.R.S.	L.O.R.S.	R.D.	?	(R.D.)	R.D.	Red Downtonian	Downtonian
					T.S.	T.S.	T.S.	T.S.	T.S.	Temeside Shales	Downtonian
Tilestones.	T. D.S.	D.S.	T. D.S.	D.S.	D.S.	D.S.	D.S.	D.S.	D.S.	Downton Sandstone	Downtonian
L.B.B.	L.B.B.		L.B.B.	L.B.B.	L.B.B.	L.B.B.	L.B.B.	L.B.B.	L.B.B.	Ludlow Bone-bed	Downtonian
Upper Ludlow Rock.	U.L.R.	U.L.S.	U.L.	U.L.	C.B.	C.B.	C.B.	C.B.	C.B.	*Chonetes* Beds.	Ludlovian
					R.B.	R.B.	R.B.	R.B.	R.B.	*Rhynchonella* Beds	Ludlovian
Aymestry or Ludlow Limestone.	A.L.	A.R.	A.L.	A.L.	A.G.	A.G.	A.G.	A.G.	A.G.	Aymestry Group	Ludlovian

A.L. = Aymestry Limestone; A.R. = Aymestry Rock; A.G. = Aymestry Group; U.L.R. = Upper Ludlow Rock; U.L.S. = Upper Ludlow Shale; U.L. = Upper Ludlow; R.B. = *Rhynchonella* Beds; C.B. = *Chonetes* Beds; L.B.B. = Ludlow Bone-bed; D.S. = Downton [Castle] Sandstone; T. = Tilestones; T.S. = Temeside Shales; R.D. = Red Downtonian; L.O.R.S. = Lower Old Red Sandstone. The heavy black line shows the limit between the Silurian and Devonian adopted by the different authors.

(1) *Proc. Geol. Soc.*, London, vol. ii, 1834, p. 13. (2) *Siluria*, 4th ed., 1867, pp. 133–4 and 142. (3) *Mem. Geol. Surv.*, vol. ii, pt. i, 1848, pp. 84–103. (4) *Advanced Text-book of Geology*, 1st ed., 1856; 6th ed., 1876, p. 213. (5) *Geology, Chemical, Physical, and Stratigraphical*, vol. ii, 1888, p. 59. (6) *Q.J.G.S.*, vol. lxii, 1906, pp. 195–8. (7) *Proc. Birmingham Nat. Hist. Phil. Soc.*, vol. xiv, 1917, p. 90. (8) *Q.J.G.S.*, vol. lxxiv, 1918–19, pp. 221–46. (9) *C.R. Acad. Sci.*, vol. clxvii, 1918, p. 705, emended in *Mém. Soc. géol. Nord.*, vol. vi, ii, 1920–2, pp. 187–8. (10) Geol. Mag., Vol. LVII, 1920, p. 164. (11) *Bull. Soc. belge Géol.*, vol. xxxi, 1921, p. 88; *Abs. Proc. Geol. Soc.*, No. 1075, p. 6.

In other words, Murchison never included the Tilestones in the *Ludlow* Beds, but when he placed them in the Silurian he considered them as a higher series.

Since the time when Murchison included the "Tilestones" in the Silurian System, the upper limit of the latter has been gradually moved higher and higher as higher and higher beds have yielded marine fossils. In England certain fish-remains occurred in association with these marine fossils. Consequently, when similar fish-remains were found in Scotland the beds containing them were removed from the Old Red Sandstone and classed as Silurian. Similarly, in England the same "Downtonian" fish-fauna was found to persist long after the marine fossils had disappeared, but owing to the entity of the fish-fauna the whole series of beds had perforce to be considered as Silurian (Ledbury Passage Beds and Red Downtonian).[1] This important point is frequently ignored by those who advocate a high limit for the Silurian.[2] Whilst it is practically impossible to draw the dividing line between the two systems in the midst of the Downtonian—which forms a faunally and stratigraphically homogeneous series—the top of that series is at least 1,500 feet *above* the higher limit adopted by Murchison for the Silurian. The accompanying table shows at a glance the curious way in which the boundary line between the Silurian and the Old Red Sandstone has been repeatedly changed. It may be noted that as early as 1856 there was a reaction in favour of considering the Ludlow Bone-bed as the base of the Old Red Sandstone, and Page maintained this opinion in spite of the opposition of Murchison (see also Banks' conclusions, quoted on page 29). Other authors—notably Prestwich—urged that the Bone-bed must at least be grouped with the Downton Sandstone and not with the Ludlow.

The whole question has been discussed from the historical standpoint by H. de Dorlodot in connexion with the problem of the base of the Devonian in the Ardennes.[3] He shows very clearly that unless one adopts the original limit of Murchison (1834–5) then Dumont's definition of the base of the Rhénan (Devonian) in the Ardennes (1845) has prior claim over Murchison's later redefinition of the upper limit of the Silurian (1848). Similar conclusions have been expressed by H. S. Williams in America,[4] and by Barrois, Pruvost, & Dubois in France.[5]

[1] Professor Hull attempted to overcome the difficulty by the creation of a "Siluro-Devonian System" to include the passage-beds above the Ludlow Bone-bed. *Q.J.G.S.*, vol. xxxviii, 1882, p. 200.

[2] Leriche, "Observations sur la limite entre le Silurien et le Dévonien . . . à propos d'une note de M. Stamp": *Bull. Soc. belge Géol.*, vol. xxxi, 1921, pp. 158–66.

[3] de Dorlodot, "Le Système dévonien et sa limite inférieure": *Ann. Soc. géol. Belg.*, vol. xxxix, 1912, Mém., pp. M 291–M 371; also Conclusions . . . , ibid., Bull., pp. B 242–5.

[4] Williams, *Bull. Geol. Soc. Amer.*, vol xi, 1900, pp. 334–5.

[5] Op. cit., 1920 (1922), pp. 205–16.

The classification adopted in this paper, by restoring the original lower limit of the Old Red Sandstone, satisfies the laws of priority both with regard to the Silurian and Old Red Sandstone in this country, and also, as will be seen in the sequel, with regard to the Rhénan (Devonian) on the Continent. It should be noted, however, that the dividing line is to be drawn definitely below the Ludlow Bone-bed.

(*a*) The Bone-bed is indissolubly linked with the succeeding sandstones by its fish-fauna. There is not one species of fish recorded from the bed which does not occur also in higher strata, whereas it is doubtful whether a single one has ever been found in lower beds.
(*b*) The Upper Ludlovian marine species which occur in the Bone-bed all range upwards into the overlying strata. Several characteristically Downtonian invertebrates occur for the first time in the Bone-bed.
(*c*) The Bone-bed passes laterally into an osseous conglomerate and then into ordinary conglomeratic sandstones which rest unconformably on underlying beds (even down to Cambrian).
(*d*) The lithological change is at this horizon.
(*e*) It is now customary to consider similar Bone-beds as the base of formations or systems (e.g. the Rhaetic Bone-bed).

(*To be continued.*)

REVIEWS.

Special Reports on the Mineral Resources of Great Britain. Memoirs of the Geological Survey.

Vol. XXV.—Lead and Zinc Ores of Northumberland and Alston Moor. By Stanley Smith, with contributions by R. G. Carruthers. pp. iv + 107, with 15 figures, 1923, price 3*s.* 6*d.* net.

Vol. XXVI.—Lead and Zinc Ores of Durham, Yorkshire and Derbyshire, with Notes on the Isle of Man. By R. G. Carruthers and Sir A. Strahan. pp. iv + iii, with 2 plates and 6 figures, 1923, price 3*s.* net.

WE welcome two further volumes of these admirable publications, dealing with the Pennine district in general, a region of particular interest to the geologist, both general and economic, with a wealth of associations with the earliest days of mining in this country. Dr. Stanley Smith makes a striking point in calling attention to the fact that the Roman Wall is situated exactly at the northern limit of the productive mining field, a coincidence too remarkable to be accidental. As is well known the Romans mined extensively both in the extreme north and in Derbyshire, and until the great industrial depression of the present years, mining, first mainly for lead and of late for zinc, has been of great importance. The recent considerable demand for fluorspar has enabled a certain amount of production to continue even under the most adverse circumstances, but of course a good deal of this has come from old dumps.

Both these memoirs give very full descriptions of the mineral

veins, flats, pipes and other characteristic structures, which may indeed be regarded as the type examples of lead-zinc ore-bodies in limestone. It is of much interest to note that in the north the payable parts of the veins are confined to high levels, in fact to hill-tops, the veins becoming barren where the outcrops descend into the valleys. This suggests that the mineralization was related to an older surface, now deeply dissected. From the practical point of view this fact of observation is most discouraging as regards further developments at greater depths, but the discovery of rich ore far below the surface in the Bradford Corporation aqueduct tunnel at Greenhow, near Pateley Bridge, is a good sign in the other direction.

All students of ore-deposits and of general geology will find much to interest them in these volumes, which will enhance the already high reputation of the series of the Special Reports on the Mineral Resources of Great Britain.

R. H. R.

Die Kriegsschauplätze 1914–1918 geologisch dargestellt: Heft 5. Argonnen und Champagne. By Dr. K. Hummel. Giessen, pp. 82, with six text-figures. Berlin: Borntraeger, 1923.

DURING the war a large number of German geologists were employed as technical advisers on the various fronts: the material then collected is now being published in a series of thirteen monographs, under the general editorship of Dr. Wilser of Freiburg i. Br. The part under review contains a comprehensive and detailed account of the geology of the well-known district of the Argonne and Champagne, including sections on physiography and hydrography, on general stratigraphy and the geological history of the district, and on the economic products. A bibliography of 75 items is a useful feature for those interested in the geology of the eastern part of the Paris Basin and the southern border of the Ardennes, these being the chief structural features included in this area. The account of the Jurassic and Cretaceous strata is very full and complete and the description of the superficial deposits occupies some twelve or thirteen pages. Much detail is given as to the water-supply, water-bearing strata and other points of immediate military interest. The work should be of considerable value during the next war.

The Geology of the Namma Coal Field, Burma. By E. Moldenke. Trans. Amer. Inst. Min. Met. Eng., vol. lxvi, 1922, pp. 299–302.

HITHERTO all coal used in Burma has been imported from Calcutta, and is consequently very expensive. There are, however, lignite deposits in the country, the most promising being the Namma field in the Northern Shan States, 30 miles south of

Lashio, the terminus of the Burma Railway, 750 miles N. of Rangoon. The lignite basin, covering about 50 square miles, consists of Tertiary strata overlying Devonian limestone. There are two chief beds of lignite, the upper one averaging about 14 feet, and the lower one ranging from 19 to 40 feet, both consisting in depth of a lustrous black lignite with a dark brown streak: it contains fixed carbon 45 per cent, volatile matter 37 per cent, ash 4 per cent. A conservative estimate of the total resources of the basin assigns 50,000,000 tons to the lower bed and 30,000,000 tons to the upper. No mining has yet been done.

REPORTS AND PROCEEDINGS.

South Wales Institute of Engineers.

Friday, 27th April, 1923.

A. E. Trueman and J. H. Davies. The Correlation of the Coal Seams of the Anthracite area of the South Wales Coalfield.

Characteristic Mollusca were described from several seams in the neighbourhood of Brynamman and Ystalyfera. The species of *Carbonicola* characteristic of the Lower Vein of Brynamman have been located in various seams from Abercrave westwards to Pembrokeshire. The assemblage of *Carbonicola* spp. with *Anthracomya modiolaris* has been found from Abercrave to Ammanford and appears to be characteristic of the Peacock or Brass Vein. An assemblage of *Naiadites modiolaris* and *Carbonicola* spp. is characteristic of the Big, Nine-feet and Stanllyd seams of Brynamman, Ystradgynlais and Cross Hands. Characteristic forms of *Carbonicola* were described from the Four-feet (Cornish) vein of Ystradgynlais and this vein is correlated with the Green Vein of Cross Hands and Caerbryn, where similar shells are found.

These fossils will make possible the correlation of the north and south crops of the field and compare closely with those of certain zones in N. Staffs and elsewhere, placed by Wheelton Hind in his zone of *Naiadites modiolaris* and *Anthracomya modiolaris*. In both areas they are followed by a zone of *Anthracomya Phillipsi*.

Geologists' Association.

Friday, 4th May, 1923.

A lecture was delivered on "The Rock-shelters and Caves of Dordogne", by Arthur L. Leach, F.G.S.

Outline of the geological and geographical features of the district traversed by the R. Vézère. Les Eyzies—the "pre-historic capital of France". River-bluffs, *champignons*, *abris*, grottoes and caverns in the vicinity of Les Eyzies, illustrated by Roc de Tayac, Rocher de la Peine, Grande Abri de Laussel, Gorge d'Enfer, Grotte des

Eyzies and Font de Gaume. Laugerie Haute : method of excavation of the archæological deposits.

The road to Le Moustier : the plateau and the incised valley of the Grande Beune. Roque St. Christophe and its mediaeval fortress. Le Moustier : upper and lower rock-shelters : preservation of type-sections of the archæological deposits. La Madeleine rock-shelter. Illustrations of the palæolithic paintings and engravings of Combarelles and Font de Gaume. The mirror of the R. Vézère.

OBITUARY.

Frederic William Harmer, J.P., M.A., F.G.S., F.R.Met.Soc.

BORN 24TH APRIL, 1835. DIED 11TH APRIL, 1923.

The death of Mr. Harmer deprives us of a man of rare ability. Apart from his scientific attainments he was noted for his business capacity, and his labours in many fields. His work in his favourite science can alone be noticed here. He was one of the decreasing number of those who, not being connected professionally with geology, contributed in very full measure to its advancement. His reputation as a geologist extended beyond Britain, and many foreign geologists made special visits to this country to see him and profit from his knowledge.

His geological work lay chiefly among the newer deposits, and he devoted himself especially to a detailed study of the Pliocene and Pleistocene accumulations of East Anglia. His work among the Pliocene beds resulted in the publication by the Palæontographical Society of his Monograph of the Pliocene Mollusca, which was practically completed when he died. It shows his painstaking methods of detailed study and will be ever of high value. His work on the Pliocene led to a comparative study of the British and foreign strata and of the conditions in which they were laid down. In this work he is seen as a bold generalizer. The attention he paid to meteorology, in connexion with the conditions of formation of the Pliocene beds, is specially noteworthy.

The same capacity for combining generalization with specialization is seen in his Pleistocene work, and he produced a series of papers of high value dealing with this subject. He eventually summarized this work in a separate memoir on " The Glacial Geology of Norfolk and Suffolk ".

Mr. Harmer served on the Council of the Geological Society, and in 1902 was awarded the Murchison Medal. He was honoured by more than one foreign Geological Society, and in 1918 the University of Cambridge conferred upon him the degree of M.A. *honoris causa*.

His kindness will long be remembered by his friends, and the ready help he gave to all who sought it should be recalled when we consider what he has done for the advancement of the science.

J. E. M.

Dr. C. I. Forsyth Major.

Dr. Charles I. Forsyth Major, F.R.S., whose death occurred on 25th March, at the age of 79, was the author of upwards of eighty memoirs published by the scientific societies of England, France, Italy, Germany, and Switzerland, on the later fossil Mammalia, their systematic morphology and geographical distribution. His work covered a wide range and included the exploration of the Tertiary, Post-Tertiary, and Recent mammals of Italy, Corsica, and Sardinia, the Miocene vertebrates of Samos, etc., and the Tertiary and Recent vertebrates of Madagascar. He discovered the first skeleton of the extinct bird *Aepyornis*, an extinct *Hippopotamus*, a giant lemur, *Megaladapis*, and a new type of ape, *Nesopithecus*, besides numerous other species. He amassed very considerable collections which were mostly deposited in the British Museum, where he was at one time temporarily employed. In his later years he spent much of his time in Corsica where he continued to pursue his palæontological studies. It is feared that much of his later work, such as that on the geological position of *Samotherium* and on the living Okapi will never be published.

Count F. de Montessus de Ballore.

BORN 1851. DIED 1923.

All students of the geological aspects of earthquakes are acquainted with the "Géographie Séismologique", a great work containing records of 160,000 earthquakes, and bringing out the principal facts regarding their distribution in space. A second general work "La Science Séismologique" appeared in 1907. In the same year the author was appointed director of the earthquake-service in Chile, which he conducted with great success. M. de Montessus de Ballore was undoubtedly in the first rank of the not very numerous scientific students of seismology, a subject whose development on modern lines owes much to his work.

CORRESPONDENCE.

THE ISLAY SUCCESSION.

SIR,—In *Proc. Geol. Soc. London*, 28th April, 1923, p. 77, Mr. George Barrow states that it is possible in discussions of Islay geology to start "from the base of the Quartzite (the Central Highland Quartzite) which occurs along nearly the whole of the south-eastern side of Islay, a little inland. Mr. Wilkinson gives the evidence that this is the base in great detail, the lowest part of the rock being often black, and at times containing slabs of underlying material (now a graphitic phyllite) fully a foot long".

Perhaps I may recapitulate in outline my reasons for disagreeing

with Mr. Wilkinson in this particular (*Q.J.G.S.*, vol. lxxii, pp. 152–5, and pl. xii).

In East Islay, for 8½ miles out of a possible 13, Mr. Wilkinson has mapped a band of slates separating the conglomeratic beds mentioned above from the main quartzite lying north-west of them. I have little doubt that fuller exposures would show this band of slates to be really continuous in Islay. At any rate, following in Mr. Wilkinson's footsteps, I have found it everywhere in a similar position in Jura, where its above-sea outcrop totals another 20 miles measured along the strike. The slates of this band I have called the Jura Slates. I agree with Mr. Wilkinson that appearances on the south coast of Islay strongly suggest that the conglomeratic group lying south-east of the Jura Slates has derived material through erosion of the latter. But I disagree with him when he declares that the Jura Slates are exposed along the crest of an anticlinal fold, and that the conglomeratic quartzite south-east of them is merely an outlier of the main quartzite farther north-west. My reasons are as follows :—

(1) There is no field-appearance suggesting the postulated fold.

(2) The Jura Slates along almost all their outcrop are assymetrical, with a grey division against the main quartzite and a black division against the conglomeratic group. (I can speak with certainty in regard to this feature in the southernmost exposure in Islay, and in all except one occurrence in Jura. At the extreme north of Jura, the group is wholly black. Unfortunately, I have no detailed notes regarding exposures in Islay, except the southern one figured op. cit., p. 154.)

(3) The conglomeratic group is everywhere distinguishable on the ground of texture, from the main quartzite occurring on the other side of the Jura Slate outcrop.

It will be seen, therefore, that the evidence which points to the conglomeratic group being later than the Jura Slates, places them at the original top, rather than the original base, of the Islay Quartzite taken as a whole.

E. B. Bailey.

Edinburgh.

PETROGRAPHIC NOMENCLATURE.

Sir,—I am led to stir up these muddy waters once more by reading Mr. Dixey's interesting account of the norite of Sierra Leone (Q.J.G.S., 1922, pt. 4). Some years ago (1918) I gave a brief account of this norite in the Geological Magazine (and, by the way, I wish Mr. Dixey had not said that I "translated Gürich's work", for the few observations that I described were my own), and I mentioned three facies, namely a pegmatitic norite, a medium-grained norite, and an aplitic norite or micronorite. Mr. Dixey recognizes the same three facies, but the rock that I called micronorite he calls beerbachite, and he gives the name norite-aplite to another rock which consists chiefly (sometimes almost wholly) of quartz, orthoclase, and acid plagioclase, with

small quantities of pyroxene, etc. He tells us that this rock is related to the dolerite dykes which cut the norite, "as much as, or even more than, to the norite."

Now, the substitution of beerbachite for micronorite is warrantable, though personally I am opposed to the practice of giving different specific names to rocks which, like norite and beerbachite, differ only in texture. But in the application of the name "norite-aplite" my views and those of Mr. Dixey are totally at variance. To me an aplitic norite, micronorite, or norite-aplite is a rock of noritic composition and aplitic texture; to Mr. Dixey a norite-aplite seems to be a rock of aplitic texture derived from a noritic magma, even though it should consist, as he says, "almost wholly of quartz and micropegmatite."

With no idea of criticizing Mr. Dixey, I just wish to ask how petrology can ever progress when it is possible for such utterly different meanings to be attached to the same name? I know that it is hopeless to expect all petrographers to adopt one system of classification, but surely it is time that we came to an agreement on a few elementary points about the construction and application of rock names?

Will not the Geological Society's Committee on Petrographic Nomenclature, which has already rendered a conspicuous service by killing off many obsolescent names, give us a further lead by laying down a few *conventions* to regulate:—

(1) The method of construction of compound names.

(2) The minimum requirements for the acceptation of proposed new specific names? (Adding, if possible, lists of those that do and those that do not fulfil the requirements.)

Because Petrographers cannot agree on all points, there is no reason why they should not try to agree on as many as possible, and the example that I have given above shows how desperate the need of some agreement is.

S. J. Shand.

University, Stellenbosch,
South Africa.
16th April, 1923.

THE

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EDITORIAL NOTES.

AN appeal has been issued on behalf of the Department of Geology at University College, Reading. Isolated departmental appeals are novel; but the times are deplorably changed, and institutions for teaching and research can barely hold their own, still less expand. But, whatever conditions may obtain in later life, youth must grow and develop, or perish. This Department is only 14 years old. During that brief period it has grown from an embryo with one junior lecturer and two elementary students to robust and active adolescence with a Professor, a Lecturer, 35 degree-students, about 70 elementary students and a Workers' Educational Tutorial Class. In spite of war-time conditions, 28 of its past students have passed the B.Sc. Examination of London University, and 3 others have taken Honours. Its activity in research is well known to our readers, for no less than 27 papers have appeared here. Almost as many, several of considerable bulk, have appeared elsewhere. The Geological Survey of New Zealand has sent its Fossil Echinoidea to be monographed from the Department; and research is in progress on many other topics.

All of this work and output has been accomplished with practically no material resources. There are no laboratories or museum—all classes are held in other departments. The sole erection belonging to the Department is an asbestos-fibre hut measuring 20 feet by 12 feet! Each year more students are attracted to Geology, and a critical stage has been reached. An effort is being made to raise £5,000, so that walls and a roof may be added to the reputation on which the Department lives at present.

The appeal, signed by Professor H. L. Hawkins and Dr. A. R. Dwerryhouse, has already met with generous response, but more help is urgently needed. Contributions, however modest, from those interested in the progress of geological knowledge, would give welcome encouragement. Cheques may be sent direct to the Professor; or, with a covering letter to explain their purpose, to the Registrar of the College.

ORIGINAL ARTICLES.

Notes on the Classification of Scottish and Moravian Teschenites.

By F. Walker, B.A.

(PLATE XI.)

THE following notes are based upon an investigation of the teschenites of the Midland Valley of Scotland, and are an attempt to produce a working classification of the teschenitic intrusions of that area. A comparison has also been made between the Scottish examples and those from some of the type localities of Moravia.

Earlier Classifications.

Before proceeding to consider the classification of the teschenites, it is perhaps advisable to give a very brief account of a few earlier attempts in this direction. The name teschenite was first used in 1861 by Hohenegger (1)[1], who applied it in a very general sense to certain igneous masses intrusive into Cretaceous strata in the neighbourhood of Teschen in Moravia. In 1866 Tschermak (2) separated from Hohenegger's teschenites the more basaltic-looking occurrences, to which he gave the name "picrite" on account of their high magnesia content (due to abundant olivine). The name "teschenite" was thus restricted to the more leucocratic varieties. Tschermak was also the first to recognize that analcite was an important constituent of teschenite, forming up to 27 per cent of the rock. He distinguished between hornblende and augite teschenites, thus making the first serious attempt at a classification.

The next great advance was made by Rohrbach (3) in 1885, but during the intervening years the great controversy over the presence of nepheline and the origin of the analcite in teschenites had arisen, nepheline-bearing teschenites from Moravia and the Caucasus being described by Tschermak and Rosenbusch, held that the analcite in teschenites was secondary, replacing nepheline—a view which he maintained throughout his later writings. Rohrbach investigated the teschenites of both Moravia and the Caucasus, but was unable to find any nepheline, even by microchemical tests. He considered that the analcite arose through decomposition of the plagioclase, which it frequently replaced. He divided the teschenites primarily into two groups, (*a*) ophitic and (*b*) non-ophitic. The latter group was further divided into several sub-groups on textural and mineralogical grounds. Hornblende was a variable but ubiquitous constituent of the second group, but was absent from the first or diabasic group. Rosenbusch recognized the value of this exceedingly careful research, but remained unconvinced that the analcite originated from plagioclase. In his last (1907) edition of *Mikroskopische Physiographie*, ii, p. 431,

[1] Figures in parentheses refer to bibliography at end of paper.

he expresses his conviction that the teschenites are to be reckoned as altered theralites.

Teall (4) was the first to recognize teschenitic intrusions in the Midland Valley of Scotland, and since his description of the Carcraig rock in 1888, numerous fresh occurrences of this type have been investigated.

In recent years the work of Bailey, Campbell, Tyrrell, and others has adequately demonstrated the primary nature of most of the analcite in these teschenites. It has also been observed that when nepheline occurs in teschenites it does *not* alter into analcite. To quote Tyrrell: "Nepheline does occur in some teschenites, and is often altered; but it does not alter into analcite. Analcite has been shown to be a primary constituent of teschenite and many other analcitic igneous rocks; but owing to its aqueous constitution, and the consequent mobility and chemical activity of its solutions, or magma, it is an extremely efficient agent of paulopost alteration in previously formed mineral constituents, with the result that the analcite itself has been regarded as secondary. In other words, the analcite is not due to the alteration of the other minerals, but the alteration is due to the analcite."

To Tyrrell (5) we owe the classification of the West of Scotland teschenites into three groups:—

(1) Glasgow type.
(2) Galston type.
(3) Cathcart type with nepheline.

Some of the East of Scotland teschenites have, however, no place in this classification, notably the rock of Spalefield, near Anstruther.

Definitions of Teschenite.

It is essential to have clear and comprehensive definitions of rock-types before attempting their classification. Modern petrological treatises are unkind to the teschenites in this respect, and the writer has not yet found two authors who give the same definition.

Hatch (6) gives the following simple definition: "The teschenites or analcite-dolerites are dyke rocks essentially composed of plagioclase felspar, augite, and analcite. Olivine is also a frequent constituent."

The objections to this definition are, first, the inclusion of the analcite-dolerites under the name teschenites, and second, the absence of any mention of amphibole as a frequent constituent. The vast majority of rocks described as analcite-dolerite have a much lower alkali percentage and are more closely related to the olivine-dolerites.

According to Iddings (7), "Teschenites are analcite-theralites composed of lime-soda felspar, analcite, augite, barkevikitic amphibole, and some biotite and apatite. The analcite may be altered nepheline. The texture is medium-grained equigranular."

When discussing theralites, Iddings points out that many rocks which have been described as teschenites are, in reality, altered theralites. Thus Iddings inclines towards the view of Rosenbusch that the analcite is derived from the decomposition of nepheline—a view which is now discredited by the majority of petrologists. A decided objection to the above definition is that the presence of barkevikite is considered essential.

Holmes (8) defines a teschenite as "an alkali-rich variety of analcite-dolerite characterized by the presence of idiomorphic purple augite or aegirine-augite, and generally containing soda-amphiboles such as barkevikite".

The only important objection to this definition is the use of the words idomorphic purple augite, for in a great many teschenites the augite, far from being idiomorphic, is strongly ophitic. Moreover, as Tyrrell points out, the term dolerite should always connote ophitic texture.

Harker (9) does not define the term teschenite, but includes the teschenites in the gabbro group, commenting upon the difficulty of drawing a line between the teschenites and the theralites.

As there are a great many textural varieties of teschenites, the ideal definition would seem to be one on a mineralogical basis only. The writer suggests the following definition as an improvement on any of the foregoing.

"Teschenites are rocks consisting essentially of plagioclase felspar (which is partially or wholly analcitized), titanaugite, and analcite. Barkevikite is often present, sometimes reaching a greater abundance than the titanaugite, and olivine is a frequent constituent." Accessory minerals may include nepheline, zeolites, alkali-felspar, aegirine-augite, biotite, apatite, ilmenite, and pyrites.

This definition has the advantage of drawing a sharp line between the analcite-dolerites (including the Crinan type (10)[1] and the augite-teschenites, without the introduction of any arbitrary condition. Analcite in certain analcite-dolerites may be observed filling cracks in the larger plagioclases, but the patchy replacement of plagioclase so characteristic of the teschenites is never seen.

Relationship of Teschenites to Theralites and Camptonites.

With increase of nepheline and decrease in the quantity of analcite the teschenites grade into the theralites, for which Lacroix (11) has recently produced a classification. The nepheline-teschenites of Cathcart and Lugar are "half-way houses" between the two types, and may be classed either with the teschenites or with the luscladite or berondrite groups of the theralites.

With diminution of the amount of analcite the non-ophitic and sub-ophitic hornblende-teschenites show a gradual passage into camptonites. Such camptonites are found in Iona and as segregations in teschenite sills at Whitehouse Point, Inchcolm, and else-

[1] See also Pl. XI, Fig. 4.

where. These segregations are of much finer grain than the normal rock, and show well-marked ocellar structure.

Suggested Classification of Scottish Teschenites.

The following classification of the Scottish teschenites is suggested :—

(*a*) *Porphyritic or Basalt Type.*

Characterized by conspicuous phenocrysts of fresh olivine and titanaugite, frequently forming glomero-porphyritic aggregations. The grain is fine to medium. (See Pl. XI, Fig. 1.)

(*b*) *Ophitic or Dolerite Type.*

Typically non-porphyritic and characterized by well-marked ophitic or sub-ophitic relationship between the titanaugite and plagioclase. The olivine is invariably serpentinized and the grain is medium to coarse. (See Pl. XI, Fig. 2.)

(*c*) *Non-ophitic or Gabbro Type.*

Typically non-porphyritic and characterized by even-grained hypidiomorphic texture. In the varieties rich in analcite both the titanaugite and barkevikite are markedly euhedral. Ophitic structure is absent and the olivine invariably serpentinized. The grain is medium to coarse. (See Pl. XI, Fig. 3.)

The above division of the teschenites into three groups has been made on textural grounds, each of the primary groups being further divided into two sub-groups :—

(1) Varieties with hornblende (barkevikite).
(2) Varieties without hornblende.

The distribution of the barkevikite is, however, so exceedingly capricious in some rocks that the value of this further division is doubtful. It is convenient to refer to teschenites containing barkevikite as hornblende-teschenites, the term augite-teschenite being reserved for varieties without barkevikite. A short description follows of typical rocks in each division.

(*a*) The rock of Spalefield, near Anstruther, may be taken as typical of this division. A detailed description of this hornblende-teschenite has been given by Dr. Flett (12) and is therefore unnecessary here. The barkevikite is not abundant, but is a fairly constant constituent, forming small idiomorphic prisms in the groundmass. Some of the titanaugite phenocrysts show a purple margin round a green centre—a reversal of the usual state of affairs.

Only one other Scottish teschenite known to the writer may be placed without hesitation in group (*a*). This is the augite-teschenite sill of Obelisk Hill, Aberdour, which has not yet been described. The outcrop possesses the shape of an inverted pot-hook and stretches from the west of Aberdour harbour to the east of Braefoot Point.

The rock shows little variety, is usually very fresh, and is of

medium grain. Under the microscope large rounded phenocrysts of unaltered olivine form the most conspicuous constituent. There are also a few smaller phenocrysts of purple titanaugite showing idiomorphism and twinning. The groundmass consists of small idiomorphic titanaugite prisms, together with small plagioclase laths and abundant analcite, usually turbid. Minor constituents include alkali-felspar, doubly refracting zeolites, biotite, ilmenite, and apatite, this last mineral forming hexagonal prisms of a much larger size than usual. The analcite has in places corroded the plagioclase, but the latter mineral may be seen quite fresh and appears to range from labradorite to oligoclase. Where the analcite comes into contact with other zeolites, it invariably presents idiomorphic faces towards them, but is allotriomorphic towards all the other minerals, filling the interspaces of the rock, as do the other zeolites. A superficial examination of sections from the summit of Obelisk Hill showed the apparent anomaly of small titanaugite crystals enclosed in large phenocrysts of olivine. On a more detailed examination, however, it was seen that after the olivine had solidified, the magma made its way along the cracks in that mineral and crystallized out finally as titanaugite and felspar. In these sections the amount of the doubly-refracting zeolites increases at the expense of analcite. Nepheline was not observed in either the Aberdour or the Spalefield rocks, and in this respect they differ from the nepheline-teschenite of Cathcart, which, if it is to be grouped with the teschenites at all, must come under this division. The Cathcart rock has, however, strong theralitic affinities. Olivine forms an abundant constituent of all the above rocks, but diminishes in amount in specimens belonging to the other two groups.

(*b*) This group includes a very large proportion of the Scottish teschenites. As an example of a true ophitic type, the teschenite of Gullane Head may be taken, for it is a well-known rock and has been carefully described by Professor Young (13). Hornblende occurs sporadically in this intrusion. A very fresh example of a sub-ophitic type is afforded by the augite-teschenite of Mons Hill. By this is meant the exposures on the eastern slopes of Mons Hill itself, and not the rock of Crossall Hill or Whitehouse Point. This teschenite shows analcitization of the plagioclase clearly and appears to be rich in soda-orthoclase. Olivine, pseudomorphed by brownish-green serpentine, is quite common, and biotite is a fairly abundant constituent. Some of the smaller titanaugite crystals are nearly euhedral, but the larger ones show a sub-ophitic relationship with the felspar and sometimes enclose small laths of plagioclase. No hornblende is present, but in one section a small crystal of fresh nepheline showing a rectangular outline was noted. A similar isolated crystal of nepheline was observed in the teschenite of Dundas. The rock from the second intrusion east of the mouth of the River Almond is a finer grained teschenite

of similar type, but contains more analcite and, in places, some barkevikite, both in parallel growth with the titanaugite and as separate prisms. Group (*b*) includes the majority of the rocks which come under the Glasgow and Galston types of Tyrrell.

(*c*) The rocks of group (*c*) appear to be confined to the West of Scotland. The rock from the margin of the Mons Hill sill at Whitehouse Point has been described as a non-ophitic teschenite (14), but cannot now be so regarded owing to the discovery by the writer of nepheline as an important constituent. This mineral is certainly present in sufficient abundance to justify the inclusion of the rock among the theralites. To obtain a true non-ophitic hornblende-teschenite we must turn to the Lugar sill, which has been exhaustively described by Mr. Tyrrell (15). In this complex intrusion it is found that the rock named lugarite fulfils the necessary conditions, and may be regarded as a hornblende-teschenite which is extremely rich in analcite. Nepheline is not an important constituent of the sections possessed by the writer, and barkevikite is present in greater quantity than titanaugite. Pseudomorphs after olivine are rare or absent.

The teschenite of Cranhill quarry, near Shettleston, affords an excellent example of a non-ophitic augite-teschenite. Euhedral prisms of titanaugite, showing well-marked hour-glass structure, are set in an aggregate of analcite and plagioclase. The plagioclase is largely analcitized. Green pseudomorphs after idiomorphic olivine are of frequent occurrence, and minor constituents include alkali-felspar, biotite, apatite, and ilmenite. In the hand specimen the rock is very dark in colour.

Moravian Teschenites.

In order to make a comparison between the Scottish and Moravian teschenites, ten sections of the latter were obtained. Five were loaned from the collection of the Sedgwick Museum in Cambridge through the kindness of Dr. Harker, three were taken from a collection illustrating Rosenbusch's *Mikroskopische Physiographie*, while the remaining two were purchased from Voigt and Hochgesang. Two of these ten slides had unfortunately to be rejected, as one from the Rosenbusch collection, labelled Neutitschein, was a monchiquite, and another purchased from Voigt and Hochgesang labelled Söhla, was a camptonite. Of the other eight sections, five were coarse, markedly ophitic augite-teschenites, greatly resembling many of the coarser Scottish rocks and almost indistinguishable from some parts of the Mons Hill sill. Four were from Teschen and one from Boguschowitz. The remaining three sections were all non-ophitic. One from Teschen was an augite-teschenite very similar to the Cranhill rock and showing the same euhedral augites with hour-glass structure. The second section (from Boguschowitz) showed an equally close resemblance to Tyrrell's lugarite, the euhedral barkevikites and titanaugites being set in

a turbid aggregate of leucocratic minerals in the same fashion. In the Moravian rock, however, the barkevikites are partly chloritized and the surrounding minerals stained green. The third and last section (from Pod Rudau) resembles the second, but is fresher. The large euhedral barkevikites and titanaugites are unaltered, and the latter have a very pronounced green margin. The leucocratic minerals consist of analcite and other zeolites, which often replace plagioclase and alkali-felspar. A few small crystals of soda-amphiboles and pyroxenes are also present, and large brownish apatites are common. The rock has a certain resemblance to the analcite-syenite of Howford Bridge, but is richer in zeolites and barkevikite. These last three sections all fall into Rohrbach's non-ophitic group.

According to the writer's classification, the five ophitic sections would all fall into group *b* (doleritic), while the non-ophitic ones might be placed with equal confidence in group *c* of the non-ophitic gabbro-like teschenites.

It is interesting to note the close resemblance between the Moravian rocks and our Scottish types, and to find lugarite represented in the former province. From the very limited material available, it appears that the Scottish classification is applicable to the Moravian teschenites.

In conclusion, the writer desires to express his great indebtedness to Dr. Harker and Dr. Thomas for the loan of sections, and to Dr. Campbell, Mr. Balsillie, and Mr. Tyrrell for much kind assistance and advice.

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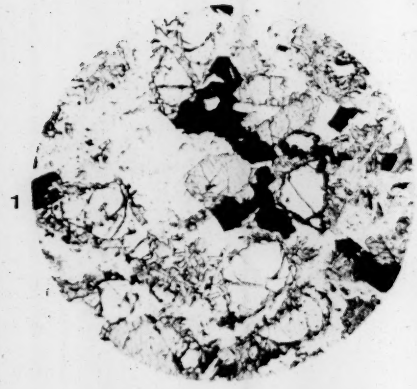
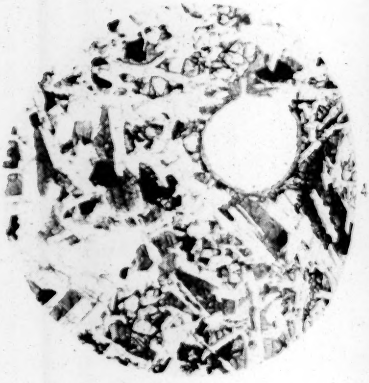




TYPES OF SCOTTISH TESCHENITES.

To face p. 219.

EXPLANATION OF PLATE XI.

FIG.

1.—Porphyritic or "basalt" type of teschenite. Obelisk Hill, Aberdour. Ordinary light, magnified 25 diameters. Phenocrysts of fresh olivine and titanaugite, and large crystals of iron ore set in a turbid ground-mass of felspars, titanaugite, and zeolites.

2.—Sub-ophitic "dolerite" type of teschenite. Shore quarter-of-a-mile east of Cramond village. Ordinary light, magnified 25 diameters. Sub-ophitic crystals of titanaugite, clear patches of analcite, and iron ores are conspicuous in a turbid aggregate consisting mainly of analcitized plagioclase.

3.—Non-ophitic "gabbro" type of teschenite. Cranhill, Glasgow. Ordinary light, magnified 25 diameters. Large euhedral titanaugites showing hour-glass structure set in aggregate of clear analcite, turbid analcitized plagioclase, iron ores, and serpentine.

4.—Crinanite, Mingulay, Outer Hebrides. Ordinary light, magnified 35 diameters. Note the dark coloured strongly ophitic pyroxene, the granular olivine, and the freshness of the leucocratic minerals as compared with teschenites. A circular analcite-filled vesicle is conspicuous.

Classification and Age of the Analcite-bearing Igneous Rocks of Scotland.

By G. W. Tyrrell, A.R.C.Sc., Ph.D., F.G.S., F.R.S.E., Lecturer in Geology, University of Glasgow.

THE Midland Valley region of Scotland contains the world's largest known development of igneous rocks carrying primary analcite. These rocks have been described in several publications during the last fifteen years, and some new rock-types have been defined.[1]

The analcite-bearing rocks are concentrated in four main areas: Fife and the Lothians; the Glasgow district; Ayrshire; and the West Coast from the Clyde region up to the Outer Hebrides. In the first three of these areas the age of most of the analcitic igneous rocks is Late-Carboniferous or Permian; in the last-named area they are most probably connected with Cainozoic volcanic activity.

The Late-Palæozoic examples occur almost entirely as sills usually not more than 200 feet in thickness; the Cainozoic masses appear both as sills and thick dykes. Volcanic or lavaform representatives of these rocks occur in numerous volcanic vents, and in two small lava fields (Mauchline, Ayrshire; Thornhill, Dumfriesshire).

A close scrutiny of the whole assemblage of analcitic rock-types in Scotland makes it clear that there two series or suites which are tolerably distinct from the petrographical standpoint, and also in respect to geological age and relations. These may be respectively called the *teschenite* series and the *crinanite* series from their most characteristic and abundant rock-types. Both the magmas represented by these rock-types may be regarded as the starting points for differentiation in two or three directions, resulting in the production of large and varied assemblages of related analcitic igneous rocks.

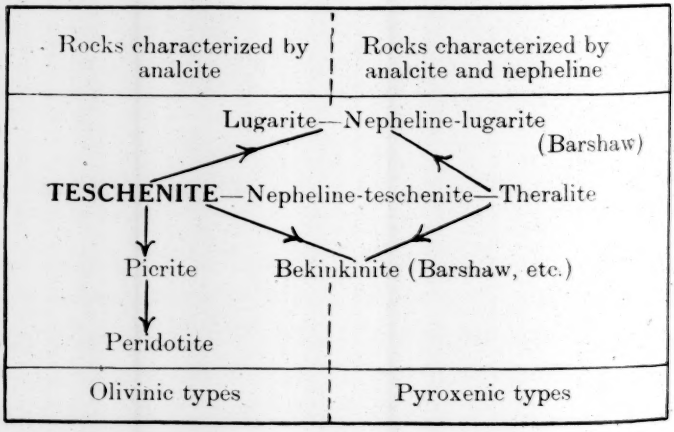
[1] For the principal references see the bibliography appended to the paper. In the text these publications are referred to by number.

The Teschenite Series.

Teschenite is analcite-gabbro, just as theralite is nepheline-gabbro and missourite is leucite-gabbro. It consists of labradorite (An 50 to An 70), analcite, titanaugite, olivine, iron-ores, and apatite. Soda-orthoclase often accompanies analcite as an important accessory; and a red soda-hornblende (barkevikite) is associated with the pyroxene either as a paramorphic alteration product or as a primary mineral. A reddish biotite may accompany the titaniferous iron-ore. The rock is typically mafelsic and may be very coarse-grained, but usually it is medium- to fine-grained, with sub-ophitic texture, and passes to doleritic and basaltic varieties in the smaller sills and towards the margins of the larger masses. Full descriptions of representative examples of this rock-type are to be found in many of the publications cited in the Bibliography (see especially Numbers 1, 2, 4, 5, 8, and 12).

Differentiation from teschenite in the ultrabasic direction by the concentration of the mafic constituents leads to the formation of picrite (*sensu stricto*),[1] and finally to peridotite when olivine is the principal mafic constituent. In the alkalic direction differentiation from teschenite leads to the formation of the highly analcitic type known as lugarite.

A subsidiary type of differentiation, with the relative concentration of pyroxene or amphibole as its main feature, and a tendency for nepheline partly to take the place of analcite, brings about such rock-types as nepheline-teschenite (Cathcart), theralite (Lugar), and bekinkinite (Barshaw; Carskeoch, etc.). The relationships of the rocks of the teschenite series are diagrammatically displayed in the following scheme:—



[1] The original *picrite* was an ultrabasic differentiate from the teschenites of Moravia. G. Tschermak, *Sitzungsber. k. Akad. Wien*, liii, 1866, p. 262.

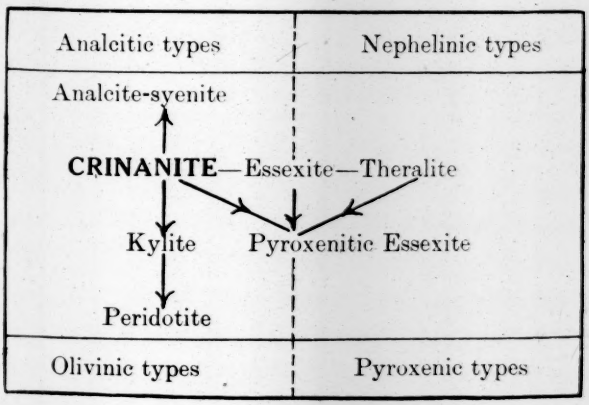
The Crinanite Series.

Crinanite was first named and described by Dr. J. S. Flett (Refs. 6 and 7) from the centre of distribution (Crinan Canal, Argyllshire) of certain olivine-analcite-dolerite dykes which are believed to be of Cainozoic age. These are ophitic dolerites with purple titan-augite, labradorite, abundant olivine, iron-ores, and a small quantity of interstitial analcite (or radial zeolites) and alkali-felspar. In the great sills of Ayrshire, Arran, and Bute, the texture becomes coarsely gabbroidal, and even pegmatitic with pyroxene crystals 3 inches in length (Clauchland Point, Arran). Gradual transitions may be traced from crinanites with indubitable fresh primary analcite to ordinary olivine-dolerites, which, however, betray their affinities by their purple titanaugite, and occasionally by the finding of a rare interstitial patch of analcite, radial zeolites, or alkali-felspar.

Assuming the parent magma to have the composition of crinanite differentiation in this series follows courses parallel to those in the teschenite series. In the ultrabasic direction the concentration of olivine leads first to the rock-type described under the name of *kylite* (Ref. 8), and finally to a peridotite which, however, is quite different in character from the ultrabasic end-product of the teschenite series. In the alkalic direction the final differentiate is *analcite-syenite* which, again, is quite a different type from lugarite, the corresponding rock of the teschenite series.

A variation in which pyroxenes are concentrated in preference to olivine, and in which nepheline becomes a prominent constituent, is seen in the porphyritic essexites (Lennoxtown, Crawfordjohn, Patna), good typical theralites (Ochiltree, etc.), and pyroxenitic essexites (Crawfordjohn, etc.).

The interrelationships of these types are exhibited in the diagram below. The parallelism between the diagrams for the two series should be noted. No nepheline-bearing type is known as yet in the crinanite series corresponding to the nepheline-lugarite of Barshaw.



Differences between the Teschenite and Crinanite Series.

The chief differences are the greater abundance of analcite in the teschenite series, of potassic felspar and olivine in the crinanite series. Plagioclase felspar also tends to be relatively more abundant in the last named, but it becomes highly sodic in composition towards the alkalic end of the series, while in the teschenite series the plagioclase remains of labradorite composition throughout. A subsidiary difference is the greater prominence of barkevikite and apatite in the teschenite series, a feature which is probably genetically connected with the relatively greater amount of water which is retained in the teschenite series as compared with the crinanite. Some of the coarser crinanite types in the thick sills of Arran contain almost as much analcite as a typical teschenite, but are distinguished by the abundance of fresh olivine.

The differences between the two series are graphically displayed in the variation diagrams Figs. 1 and 2. These have been drawn from the measured and computed modes of two typical rock series, the teschenite diagram (Fig. 1) mainly from the Lugar rocks, the crinanite diagram (Fig. 2) from the kylites and crinanites of the Dalmellington-Patna district and the analcite-syenite of Mauchline. The percentages of mafic constituents in the rocks have been plotted along the abscissæ, and other mineral constituents along the ordinates. It is believed that this procedure gives the best picture of the general course of differentiation; since this process, by whatever mode it is conceived to take place, tends in general to the separation of the calc-ferro-magnesian or mafic constituents (chiefly olivine and pyroxenes) from the alkalic constituents (alkali-felspars and felspathoids) and quartz.

The curves are based mainly on the olivinic and analcitic branches of the two series, i.e. the rocks found on the left-hand sides of the above diagrams. Some of the pyroxenic essexites and theralites, and bekinkinite, do not fit either group of curves very well. They tend to fit the crinanite curves for olivine and orthoclase, but are nearer the teschenite curves for analcite (and nepheline) and plagioclase. Thus in some respects the pyroxenic types are intermediate between the two series.

The chemical characters of the two series are exhibited in Tables I and II, in which are collected representative analyses of the main rock-types.

Age Relations.—In discussing the perplexing question of the ages of the analcite-bearing rocks of Scotland, the following five groups must be considered separately:—

1. Teschenite series of Ayrshire, Glasgow, the Lothians, and Fife.
2. Analcite-syenite—crinanite—kylite—peridotite sills of Ayrshire.
3. Crinanite—kylite sills of Arran and Bute.
4. Large crinanite dykes of the mainland and islands of the Clyde Estuary.
5. Crinanite dykes of the western coasts and islands.

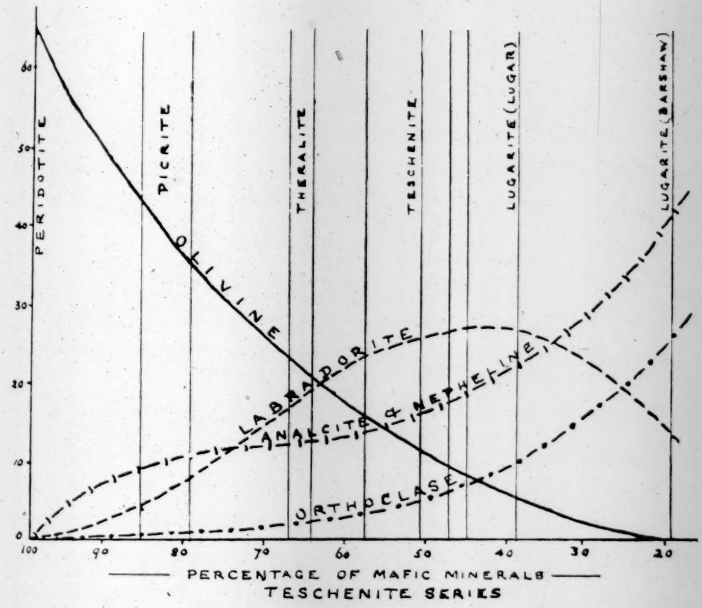

PERIDOTITE
PICRITE
THERALITE
TESCHENITE
LUGARITE (LUGAR)
LUGARITE (BARSHAW)
OLIVINE
LABRADORITE
ANALCITE & NEPHELINE
ORTHOCLASE
PERCENTAGE OF MAFIC MINERALS
TESCHENITE SERIES

FIG. 1.

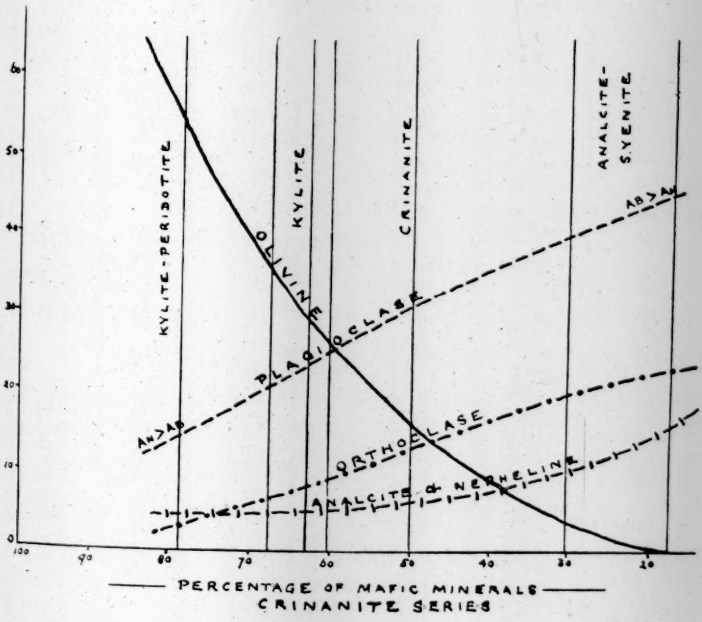

KYLITE-PERIDOTITE
KYLITE
CRINANITE
ANALCITE-SYENITE
OLIVINE
PLAGIOCLASE
An>Ab
An<Ab
ORTHOCLASE
ANALCITE & NEPHELINE
PERCENTAGE OF MAFIC MINERALS
CRINANITE SERIES

FIG. 2.

TABLE I.—THE TESCHENITE SERIES.

	(1)	(2)	(3)	(4)	(5)
SiO_2 . .	46·44	45·57	44·47	40·35	40·87
TiO_2 . .	1·45	2·41	2·73	2·12	2·85
Al_2O_3. .	16·36	14·95	7·59	3·75	16·23
Fe_2O_3 .	4·91	2·82	6·25	3·53	1·31
FeO . .	5·89	7·35	9·57	9·86	7·37
MnO . .	·19	·31	·49	·20	·64
MgO . .	2·20	6·19	11·93	25·69	9·83
CaO . .	5·25	8·27	10·24	4·64	11·13
Na_2O .	8·81	4·33	4·27	3·14	2·78
K_2O . .	1·59	2·16	1·46	·80	·53
H_2O+ .	4·83	3·93	·73	5·28	4·28
H_2O- .	1·30	·97	·48	·83	1·35
CO_2 . .	none	·18	tr.	tr.	·38
P_2O_5 . .	·87	·67	·54	·25	·52
(BaSr)O .	·09	·07	n.d.	·06	none
Rest . .	—	—	—	—	·27
	100·18	100·18	100·75	100·50	100·34

(1) Lugarite, average of two analyses.
(2) Teschenite, average of five analyses.
(3) Picrite, Lugar.
(4) Peridotite, Lugar.
(5) Bekinkinite, Barshaw. The "Rest" includes FeS_2, ·21; (NiCo)O, ·06; and Li_2O, ? tr.

TABLE II.—THE CRINANITE SERIES.

	(1)	(2)	(3)	(4)	(5)
SiO_2 . .	56·44	44·69	44·70	44·18	43·94
TiO_2 . .	1·16	·46	2·34	1·30	2·45
Al_2O_3. .	15·54	14·17	14·50	10·67	14·03
Fe_2O_3 .	3·27	3·35	2·95	·97	1·95
FeO . .	3·67	10·86	8·05	10·03	11·65
MnO . .	n.d.	·31	·30	n.d.	·32
MgO . .	1.73	6·41	7·82	17·77	10·46
CaO . .	4·16	10·28	11·25	9·75	8·99
Na_2O .	5·81	3·64	4·10	2·37	2·68
K_2O . .	4·27	2·01	1·71	1·23	·33
H_2O+ .	2·06	2·53	1·47	·97	2·31
H_2O- .	·44	1·05	·24		·85
CO_2 . .	·97	none	·11	tr.	·16
P_2O_5 . .	·83	·45	·71	·38	·20
(BaSr)O .	n.d.	tr.	tr.	n.d.	none
Rest . .	—	—	—	—	·10
	100·35	100·21	100·25	99·83	100·42

(1) Analcite-syenite, Howford Bridge, Mauchline.
(2) Crinanite, Howford Bridge, Mauchline.
(3) Porphyritic Essexite, average of two analyses.
(4) Kylite, Benbeoch, Dalmellington.
(5) Crinanite, Cainozoic dyke, Inver Lodge, Jura. The "Rest" includes FeS_2, ·04; Fe_7S_8, ·06; Cr_2O_3, tr.

1. TESCHENITE SERIES OF AYRSHIRE, GLASGOW, THE LOTHIANS, AND FIFE.

Ayrshire.—There are two main groups of teschenite occurrences in Ayrshire; one in the district of Lugar and Old Cumnock,

embracing the Lugar, Craigens, Glaisnock, Glengyron, Craig Farm, Carnevan Hill, and Carskeoch Hill intrusions; and another in North Ayrshire, including the sills of Galston, Stewarton, Ardrossan, and Saltcoats. These mainly intersect the Carboniferous sediments up to the Coal Measures. The Polbaith sill (Galston) appears to cut an agglomerate vent which may be of Permian age, but this occurrence requires further investigation. The critical locality, however, is that of Carskeoch Hill, near Patna, where rocks of the teschenite series, along with a crinanitic type, occur as intrusions in a Permian volcanic vent. This remarkable assemblage is dealt with in more detail later (p. 256).

Glasgow District.—The Glasgow teschenites intersect the strata of the Millstone Grit and Coal Measures.

The Lothians.—According to the Edinburgh Memoir (4, p. 275), the alkaline, analcite-bearing intrusions belong to an earlier set (quartz-dolerites being the later) which are regarded as contemporaneous with, and allied to, the Lower Carboniferous lavas. They are believed to represent the underground part of this igneous episode. This conclusion is supported by their absence above the Index Limestone horizon of the Carboniferous Limestone Series.

At Inchcolm, Campbell and Stenhouse found a dyke of quartz-dolerite cutting the teschenite-picrite sill of that island. The conclusion that the teschenites are prior to the quartz-dolerites is reinforced by similar evidence afforded by a quarry at Ochiltree Mill, south of Linlithgow (4, p. 275; and *Ann. Summ. Prog. Geol. Surv. for* 1904, 1905, p. 118).

The view that the alkaline intrusives are related to Lower Carboniferous vulcanicity is also taken in the East Lothian Memoir (3, p. 99), although most of the basic alkaline, analcite-bearing rocks are intrusive into strata younger than the latest trachytic lavas of that region. The Gosford Bay teschenite intersects beds of the lower part of the Carboniferous Limestone Series. The monchiquites and analcite-basalts of East Lothian are remarkably similar to the rocks intrusive into the Permian volcanic vents of Fife and Ayrshire. It is at least a possibility, therefore, that they are really connected with late-Carboniferous or Permian vulcanicity (14, p. 358).

Fife.—The eighty volcanic vents of Fifeshire between Largo and St. Andrews have been assigned by Sir A. Geikie with considerable probability to the Permian.[1] In all respects they are identical with the Permian vents of Ayrshire, and carry small intrusions of basic analcite- or nepheline-bearing rocks. The great assemblage of sills which occurs in central Fife contains rocks of varied petrographical types. Some are quartz-dolerites; others, such as that of Spalefield, are of teschenitic affinities.[2] An examination of the Survey slide of this rock shows that it has resemblances to the

[1] "Geology of East Fife": *Mem. Geol. Surv.*, 1902, p. 279.
[2] Ibid., p. 392. See Ref. 15.

Cathcart type of teschenite, but especially to the bekinkinite modification of Barshaw and of many new Ayrshire localities. Still other masses show affinities to crinanitic types. Thus at New Gilston, Miss A. T. Neilson has collected a typical crinanite; whilst the Survey slide of the Drumcarrow Hill intrusion, 3 miles S.W. of St. Andrews, shows a rock of the same character, rich in fresh olivine and with fresh analcite in the interspaces between the felspars. A complete petrological survey of these Fifeshire intrusions is much to be desired (Ref. 15).

2. Analcite-Syenite—Crinanite—Kylite—Peridotite Sills of Ayrshire.

These may be roughly divided into three geographical groups: (a) the Dalmellington or Kyle assemblage, numerous large intrusions including the type kylite occurrence of Benbeoch; (b) a series of small masses occurring along the line of the valley of the River Ayr and including the type occurrences of analcite-syenite; (c) a series of large sills in the north central part of the county, stretching from Craigie, near Kilmarnock, to Troon. The Kyle sills are intrusive into Coal Measures. The Ayr Valley intrusives cut all members of the Carboniferous formation, and at least three in the Mauchline area cut the Permian lavas. The Craigie-Troon sills cut strata up to Coal Measures.

Carskeoch Hill provides the best evidence that both the teschenite and crinanite series are connected with late Carboniferous or Permian vulcanicity. The exposures indicate an agglomerate vent which is injected, along with the surrounding baked shales, by irregular sill-like intrusions of a very variable teschenitic rock rich in barkevikite. The most abundant type is akin to the bekinkinite differentiate of the teschenite series. This passes on the margins of the intrusions to a monchiquite which, in places, carries huge phenocrysts (or xenocrysts) of biotite, hornblende, and augite. The whole mass is again intruded by what appears to be a ring-dyke of a crinanitic rock (the Carskeoch "essexite"). Hence this occurrence shows the essential contemporaneity of the analcite rocks, amongst which the crinanites are probably slightly the younger, and their association with an undoubted Permian vent. The next vent to the west, Carclout, has an intrusion of porphyritic essexite, a characteristic member of the crinanite series (Ref. 8).

The petrography of the Mauchline lavas (Ref. 8), showing an abundance of basic, analcite- and nepheline-bearing basalts, is clearly in accord with the view that the teschenite and crinanite series represent the underground manifestations of the Permian igneous episode.

3. Crinanite-Kylite Sills of Arran and Bute.

The Triassic rocks of the south-eastern quarter of Arran are intruded by numerous basic sills, of which those of the Clauchland

Hills, Monamore Glen, King's Cross, and Dippin are the most important. For the most part these rocks are perfectly typical crinanites. A mafic modification, kylite, is sparingly present, but the analcite-syenite differentiate has not been found. Very coarse, even pegmatitic, patches are known (Clauchlands Point and King's Cross), and these tend to be richer in analcite than the dominant type.

These rocks must be post-Triassic, and can hardly be other than of Cainozoic age. The meagre evidence available [1] goes to show that they are among the earliest, if not the earliest, of the Cainozoic suite. They appear to avoid the great vent and large granitic areas of the island; and there is good evidence that they constitute, in various modifications, the basic members of the composite sills and hybrid rocks, the mélanges of basalt and felsite, dolerite and granophyre, gabbro and granite, which occur so abundantly in the southern part of Arran.

In Bute the "Permo-Carboniferous" sill described by Dr. W. R. Smellie [2] is a typical crinanite identical in petrographical characters with those of Arran. It is intersected by a composite sill of hypersthene-dolerite and quartz-porphyry identical with that of Bennan Head in the south of Arran, and therefore almost certainly Cainozoic. Both intrusions cut the Lower Carboniferous lavas of South Bute.

4. Crinanite Dykes of the Mainland and Islands of the Clyde Estuary.

Of the many thousands of basic dykes which intersect rocks of all ages up to the Triassic along the shores of the Clyde Estuary, the larger ones frequently turn out to be crinanites of very much the same nature as those of the Arran sills. Some examples have been described in previous papers (Refs. 9, 13, 14), and many others have now been found.

The most frequent trend of these dykes is N.W.–S.E., and their average thickness is between 20 and 30 feet. Examples, however, are known of 40 and 60 feet (Inverkip, Renfrewshire), and 70 feet (Kildonan, Arran). The Inverkip dykes show exactly the same kind of felsic segregation veins and patches as some of the Arran sills.

Three of the dykes (Auchinweet Burn, Yonderton Burn, Failford) which intersect the Permian red sandstones overlying the Mauchline lavas are of crinanitic type, although their characters are somewhat obscured by alteration.

From the evidence of the Arran occurrences, which intersect Triassic rocks, this group of dykes is believed to be of Cainozoic age. They may, perhaps, represent the feeders of the crinanite sills.

5. Crinanite Dykes of the Western Coasts and Islands.

The type crinanite was first described by Dr. J. S. Flett as an example of a swarm of dykes whose centre lay near the Crinan

[1] Tyrrell, "The Petrography of Arran, III": Geol. Mag., 1916, p. 196.
[2] "Igneous Rocks of Bute": *Trans. Geol. Soc. Glasgow*, xv, pt. iii, 1916, p. 364.

Canal [1] (Refs. 6 and 7). They are associated with olivine-dolerites which differ from them only in the absence of analcite, and also with certain monchiquites and camptonites. These dykes have the characteristic N.W.–S.E. trend of the Cainozoic suite. They intrude rocks of ages ranging from the Lewisian of Lewis,[2] and the Dalradian of the western and south-western Highlands, to the Cainozoic lavas of Mull and Skye (Ref. 7). In a visit to western Skye in 1913 the writer found a dyke of quite typical crinanite cutting the Cainozoic basalt lavas near Idrigil Point, west of Uig. The lavas themselves at this locality are rich in interstitial zeolites, as has also been recorded for the lavas of other parts of Skye.[3] In another paper the writer has shown that there is chemical similarity between the crinanites and the Cainozoic basalts (Ref. 14, p. 361), and has raised the question as to whether the crinanite dykes are the hypabyssal representatives of the magma that gave rise to at least some of the basalts. On the Argyllshire mainland it has been shown that the crinanite dykes intersect the E.–W. quartz-dolerite dykes which are certainly not earlier than Permo-Carboniferous (Ref. 7, p. 41). The weight of evidence is therefore decidedly for the Cainozoic age of the crinanites and associated rocks in their type region of the western Highlands.

Conclusions.—The data as to age relations assembled in the foregoing contain nothing absolutely inconsistent with the idea of a Cainozoic age for the whole of the intrusive analcite-bearing igneous rocks of Scotland. Not even the priority of the teschenites to the quartz-dolerites at Inchcolm and elsewhere is inconsistent with this view, for the writer holds that the age of the last-named group is by no means proved to be Permo-Carboniferous. Certain facts, however, such as the petrographical affinities of the dated Mauchline lavas to the analcite-bearing rocks, their association with Permian vents, etc., make the hypothesis of Cainozoic age highly improbable. The weight of evidence makes it all but certain that the teschenite group, at any rate, is late-Carboniferous or Permian. There is somewhat less certainty regarding the age of the Ayrshire analcite-syenite—crinanite—kylite sills. As has been seen, some of these cut the Permian lavas. But their geographical association with the Permian lavas and vents of Ayrshire (and Fife ?), and the occurrence of crinanitic types within the vents, make their Permian age highly probable.

If the Permian age of the Ayrshire occurrences be thus accepted, we are then faced with the problem of the recurrence of practically identical rock-types in the Cainozoic, for the post-Triassic crinanite-kylite sills and dykes of Arran, Bute, and the Clyde Estuary can

[1] *Summ. Prog. Geol. Surv. for* 1909, 1910, p. 52.

[2] A. Stevens, "Geology of the Stornoway District of Lewis": *Trans. Geol. Soc. Glasgow*, xv, pt. i, 1913, pp. 51–63.

[3] A. Harker, "Some Aspects of Modern Petrology": *Rept. Brit. Assoc.*, 1911, p. 378.

hardly be other than of Cainozoic age. It has further been shown (p. 258) that the evidence is quite as strong, if not stronger, for the Cainozoic age of the crinanite dyke assemblage of the Western Highlands and Islands.

It is possible that a slight petrographical difference may be demonstrated between the Palaeozoic and the Cainozoic crinanites. So far as the evidence goes, the latter seem to be relatively poor in potash (cf. analysis of Jura crinanite with the crinanite of Howford Bridge and the kylite of Benbeoch, Table II). Also the analcite-syenite differentiate has not yet been found among the Cainozoic types, although the alkali-syenite of Carsaig Bay, Mull, approaches closely in chemical composition to that type.[1] The Cainozoic crinanites do carry numerous leucocratic veins and patches, but these always show dominant calcic plagioclase and are to be regarded merely as leucocratic varieties of crinanite or crinanite-aplite. More analyses, especially of the Arran sills, are urgently needed to clear up these and other points.

The intrusion of analcite-bearing rocks, therefore, appears to have ended the Palaeozoic cycle of eruption in the West of Scotland and to have begun the Cainozoic cycle. It seems probable that, as igneous activity died away in late Palaeozoic or early Mesozoic times, the magma basins which had supplied the crinanite sills were frozen solid. They thus remained quiescent during the long Mesozoic era of igneous inactivity; but on the inception of Cainozoic vulcanicity, they were the first foci to be reawakened. Thus it is possible to explain the geographical overlapping of the Palaeozoic and the Cainozoic analcitic igneous rocks, and the great development of the latter, especially in the Clyde region, within the sphere of influence of one of the largest Cainozoic magmatic centres, namely, Arran. In course of time some magmatic material (mostly acid) proper to the Cainozoic igneous episode worked upwards and mingled with the relic Palaeozoic magmas, producing the varied phenomena of composite dykes and sills, hybrid rocks, and acid-basic mélanges.

It is possible that the crinanite magma represents only a slight modification of the universal basaltic layer which is supposed immediately to underlie the crust and to have supplied the material for the great basalt floods of all ages.[2] It is significant that many of the most notable localities for zeolite minerals occur in the great plateau basalt regions and that these minerals are genetically associated with the basalts.

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[1] *Ann. Summ. Prog. Geol. Surv. for* 1912, 1913, p. 70.

[2] R. A. Daly, *Igneous Rocks and their Origin*, 1914, p. 164. H. S. Washington, "Deccan Traps and Other Plateau Basalts": *Bull. Geol. Soc. Amer.*, xxxiii, 1922, pp. 765–804.

(3) Mem. Geol. Surv. Scotland: *The Geology of East Lothian*, 1910, chaps. viii, ix, x.
(4) Mem. Geol. Surv. Scotland: *The Geology of Edinburgh*, 1910, chaps. xiv, xv.
(5) Mem. Geol. Surv. Scotland: *The Geology of the Glasgow District*, 1911, chap. iv.
(6) Mem. Geol. Surv. Scotland: *The Geology of Knapdale and Jura*, 1911, pp. 116–18
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(15) D. Balsillie, "Notes on the Doleritic Intrusions of East Fife": Geol. Mag., Vol. LIX, 1922, pp. 442–52.

On a Hitherto Unrecorded Intrusion from the Lleyn.

By Albert Heard, M.Sc., F.G.S., University College of South Wales and Monmouthshire.

During the last summer, whilst mapping the district between Nevin and Clynnog-fawr, I discovered the intrusion which is described in this communication. I can find no reference to it, either in geological maps of the Lleyn or in any geological literature, and conclude that the occurrence has not been placed on record.

The igneous rock outcrops about half a mile east of Llithfaen, north of the Tan-y-bwlch farm on the Nevin-Llithfaen road, and it is situate due east of the farm Ciliau-canol.[1] There are several good exposures on the western and northern margins where the boundary of the igneous rock is well marked. The eastern junction exhibits no fresh rock, but the uncultivated ground is covered with débris from the rock below, and presents no difficulty in mapping. Unfortunately, the southern margin is not so well marked, as the outbuildings, etc., of the Tan-y-bwlch farm have been built near the junction; but the igneous rock probably does not extend beyond the line indicated on the sketch-map (Fig. 1).

The outcrop of the Ciliau-canol intrusion is in the form of a lenticle with the major axis running approximately north-west–south-east. The rock is intrusive into arenaceous mudstones of Lower Ordovician age,[2] which have a dip of about 35° in a north-west

[1] See 6 in. top. map Carnarvonshire, Sheet xxxii, N.E.

[2] The exact horizon, etc., of these sediments will be discussed elsewhere in the near future: "The District between Nevin and Clynnog-fawr."

direction. The country rock along the south-western edge has been hardened, and in places has resisted weathering to a greater extent than the marginal igneous rock, consequently forming a small ridge.

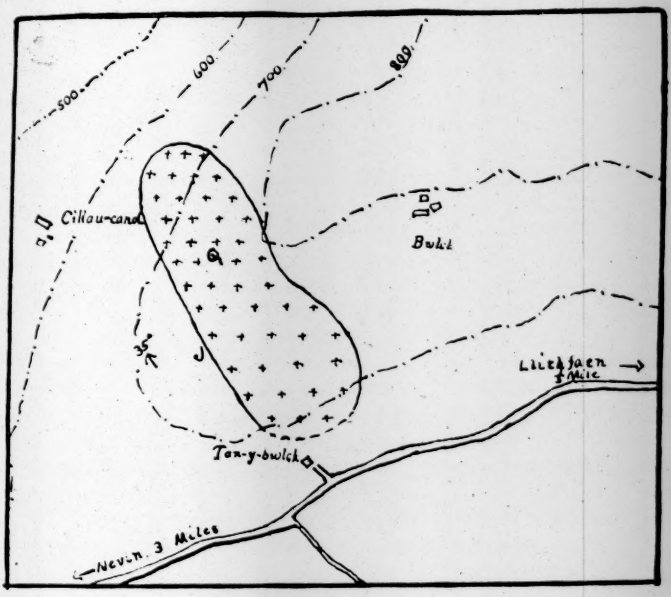


FIG. 1.—Map of the Ciliau-canol intrusion.

The freshest samples of igneous rock have been obtained from a small quarry (Fig. 1, Q), which presumably has been worked to supply building material for the neighbouring farms. The rock is well jointed, and exhibits considerable weathering along the joints. The normal rock presents a medium-grained leucocratic and spotted appearance, due to the dark idiomorphic hornblende crystals, which are surrounded by yellowish-brown and white

felspars with well-marked cleavage surfaces. Hornblende crystals 0·4 cm. long have been observed.

The actual junction of the igneous and sedimentary rocks is exposed at one place only (Fig. 1, J). The intrusive rock has been chilled, and forms a finely textured dark-grey rock, with an almost flinty appearance; minute phenocrysts of felspar and still smaller dark phenocrysts of ferro-magnesian minerals can be observed with the aid of a hand-lens.

The Normal Rock.

The normal rock has a typical granitic structure with a medium-grained texture, and under the microscope is seen to consist essentially of felspars, hornblende, and quartz, with iron ores, biotite, chlorite, etc. The quartz, which is fairly abundant, occurs as allotriomorphic grains filling up the interspaces between the other constituents. It calls for but little special description; its most interesting feature is the presence of an unusually large number of solid inclusions, which impart a cloudy appearance to many grains. In most cases these inclusions are scattered irregularly, and the characteristic "straight line" liquid inclusions are present only in a few occurrences. Amongst the solid inclusions apatite, amphibole needles, and rutile are abundant. The rutile inclusions frequently occur as relatively large, well-rounded foxy-red granules. The apatite and rutile inclusions are largely concentrated in the quartz areas, and are of rare occurrence in the felspars and ferro-magnesian constituents. Dr. J. V. Elsden[1] notes a parallel case in the St. David's Head rocks, where he describes the concentration of apatite in quartz areas, and suggests two possible explanations, viz. "either the separation of apatite was delayed by the presence of some substance which increased its solubility, or it was rejected by the pyroxenes owing to some peculiarity of surface tension, leading to capillary repulsion instead of attraction". As both rutile and apatite are concentrated in the quartz areas in the case of the Tany-bwlch intrusion, it is improbable that the first of Dr. Elsden's suggestions will account for their concentration. His second suggestion may possibly account for their presence in the quartz areas. At least two distinct types of *felspar* are present—plagioclase and weathered potash felspars. The *plagioclase felspars* occur in well-developed idiomorphic crystals. These felspars exhibit a well-marked zonal structure, with the more calcic type of plagioclase at the centre. Most of these crystals are fairly fresh, but their peripheries usually show great alteration. In a few cases, cross-hatching has been observed in fairly fresh portions of the outer edges of the zonal felspars; this suggests the presence of oligoclase-microcline. In composition the majority of the crystals range from a labradorite and andesine-labradorite at the centre to

[1] *Q.J.G.S.*, vol. lxiv, 1908, p. 289.

oligoclase-andesine, and in a few cases oligoclase towards the margin, followed by oligoclase-microcline, or possibly in some cases by microperthite. The potash felspars are relatively abundant, but are subordinate to the plagioclase felspars described above. *Microcline* is present in the rock in subhedral crystals. These crystals have turbid borders, and in most cases their crystallization has preceded that of the quartz. *Orthoclase felspar* occurs sparingly in turbid crystals with Carlsbad twinning, and has the usual dusty alteration products with sericite laths arranged along the cleavage planes. *Perthite* and *micro-perthite* are present in larger proportions than the orthoclase felspar. There are at least two distinct generations of felspars in the normal rock. The euhedral and subhedral forms of the zonal plagioclase felspars were probably crystallized before intrusion, whilst the potash felspars crystallized after intrusion and were moulded on the existing phenocrysts, in addition to their forming individual crystals. *Green hornblende* is the dominant ferro-magnesian mineral. It has a strong pleochroism (x—yellowish-green, y—yellow, z—greenish-brown) and a maximum extinction angle of 25°. The crystals are generally idiomorphic, as short or elongated prisms with the characteristic cross-section, and are associated with numerous granules of iron ores. *Rhombic pyroxenes* are not present in an unaltered form, but pseudomorphs of bastite, and still more frequently a colourless to pale-green, fibrous, highly birefringent amphibole, apparently after a rhombic pyroxene, suggest that originally rhombic pyroxenes were relatively abundant in the rock. These pseudomorphs are often present in the form of elongated prisms. *Biotite* is of rare occurrence, and is absent from some of the sections examined. *Apatite* occurs in the usual prismatic form, and invites no special description; it contains numerous small inclusions and occasionally long central cavities. *Iron ores*, both magnetite and ilmenite, are generally associated with the altered ferro-magnesian minerals. *Chlorite* is fairly common, mainly after amphibole, and generally occurs as irregular aggregates of small flakes. Occasionally a little granular sphene is associated with the chlorite. Small patches of chlorite are present also in the altered felspars. *Epidote* of secondary origin is present in the hornblende, plagioclase, and chlorite. A few slightly greenish-yellow euhedral crystals have been noted, which may possibly be pyrogenetic in the rock. These are faintly pleochroic (colourless to pale yellowish-green), and in one section of the rock a crystal of epidote has been noted which encloses a brownish core without any cleavage; this centre portion is in parallel orientation with the surrounding epidote and is presumably *allanite*.

The normal rock has an average specific gravity of 2·75, and a silica content of 60·3 per cent. Its potash-felspar content, although subordinate to that of the line felspars, is fairly high, and the rock is not far removed from the monzonite type. The rock is perhaps best described as a quartz-diorite.

The Marginal Rock.

Towards the boundary of the intrusion there is a marked increase in the basicity of the rock. A section, taken about 10 yards from the margin, shows, as compared with the normal rock, a larger proportion of zoned plagioclase felspars mainly labradorite to andesine—with a corresponding diminution of potash felspar. These plagioclase felspars are not rimmed with potash felspar, as are those of the normal rock. Interstitial primary quartz is present in relatively small amounts when compared with that occurring in the normal rock; but there is a marked increase in the amount of idiomorphic iron ore, and the apatite crystals are more numerous and larger. The ferro-magnesian minerals are represented mainly by chlorite, fibrous amphibole, and a little bastite.[1] A single small patch of micropegmatite was observed in this type; this is the only occurrence of micropegmatite which has been noted in any of the numerous thin sections from different parts of the Ciliau-canol intrusion.

Specimens taken about 1 foot from the margin show the character of the chilled edge. It is a porphyritic rock with phenocrysts of felspars and ferro-magnesian minerals in a fine-grained groundmass, consisting mainly of felspar, quartz, and rhombic pyroxene. *The felspar phenocrysts* consist entirely of plagioclase, which is mainly idiomorphic with a strong zonal structure. In composition, these phenocrysts generally range from oligoclase-andesine in the outer portion to labradorite in the centre. The border of potash felspar found round the zoned felspars of the quartz-diorite is absent from this chilled portion of the rock. Many of the phenocrysts show a corroded border, especially well marked in the case of the larger crystals, which have often become well rounded. A few smaller idiomorphic phenocrysts of a plagioclase felspar are present, and from their extinction angle are seen to be oligoclase-andesine. *Augite* occurs as allotriomorphic phenocrysts surrounded by intensely pleochroic biotite, which is present in rather indefinite patches with its associated chlorite and magnetite. The augite is colourless, and is remarkably free from inclusions. *Rhombic pyroxene* is present in the form of phenocrysts and also in a larger proportion in the groundmass. It consists of a variety poor in iron, as it is almost colourless in most of the crystals noted. A few crystals are slightly pleochroic (x—yellowish, y—yellowish, z—faintly greenish). Many crystals show a rather patchy alteration to bastite. The rhombic pyroxenes in the groundmass are mostly granular, though some crystals show idiomorphism. *Biotite*, in the form of irregular laths, is relatively abundant.

The groundmass consists of a finely crystalline aggregate of quartz, felspar, rhombic pyroxene, and iron ores. It is difficult

[1] I have been unable to obtain a fresh specimen of this type of rock.

to determine the exact nature of the felspars of which the groundmass is largely composed. The minute felspars show no trace of twinning, but have generally the peculiar extinction so characteristic of the cryptoperthite type. Occasionally larger crystals of oligoclase-andesine are present, and rarely some orthoclase showing Carlsbad twinning. The iron ores, apart from the large granules associated with the ferro-magnesian minerals, are generally in the form of minute perfect octohedra of magnetite. The most interesting features of this chilled type of rock are the great development of biotite and of monoclinic, and more especially of orthorhombic pyroxenes, and the absence of hornblende, which is only rarely present as inclusions in the plagioclase phenocrysts. The evidence of the plagioclase phenocrysts suggests that the rock was not entirely liquid on intrusion, for the crystals have been partially resorbed, presumably by the sudden increase in temperature caused by the latent heat liberated by the rapid crystallization.

The Invaded Sediments.

The invaded sediments, which consist of dark-grey mudstones, have been intensely thermo-metamorphosed by the igneous intrusion, and form a dark, hard hornfels. Under the microscope, the altered rock, at about 10 yards from the junction, exhibits a well-marked spotting, the spots consisting of ovoid spaces which are lighter in colour than the surrounding groundmass. The ovoid spaces consist of shimmer-aggregates of some strongly depolarizing micaceous material, which frequently appears to have a rough concentric arrangement. They probably represent either incipient or weathered cordierite crystals. The groundmass has a patchy pale-brown colour, due presumably to aggregated minute flakes of brown mica. Minute quartz crystals, both angular and rounded, can be observed. Opaque material, probably graphite and iron ores, is scattered abundantly throughout the rock, but practically all the larger fragments are confined to the groundmass. Andalusite occurs sparingly in the form of irregular granular aggregates. Nearer the junction, the ovoid spaces break down, and the altered cordierite forms a much larger proportion of the hornfels. The quartz crystals become larger, and minute blebs of quartz appear in the imperfect cordierite. Many of these quartz blebs and some of the opaque inclusions are surrounded by a yellowish-brown border, which is not a pleochroic halo. This yellowish-brown material may be *pinite*. The cordierite hornfels has lost almost all trace of clastic structure, and I have observed no schistose characteristics in the thin sections examined.

The Nature of the Intrusion.

The mudstones, into which the quartz-diorite is intruded, have a strike running approximately north-east–south-west (Fig. 1),

whilst the major axis of the lenticular outcrop of the Ciliau-canol intrusion is approximately at right angles to the direction of the strike. The igneous rock thus cuts across the bedding-planes of the sediments. This transgression across the strike suggests that the occurrence forms part of a stock; the quartz-diorite possibly representing the basic upper margin of a granite mass. This assumption is supported to a certain extent by the granitic structure of the rock and the almost total absence of micropegmatite, although even a granophyre laccolith generally has a granitic structure towards the outer edge.[1]

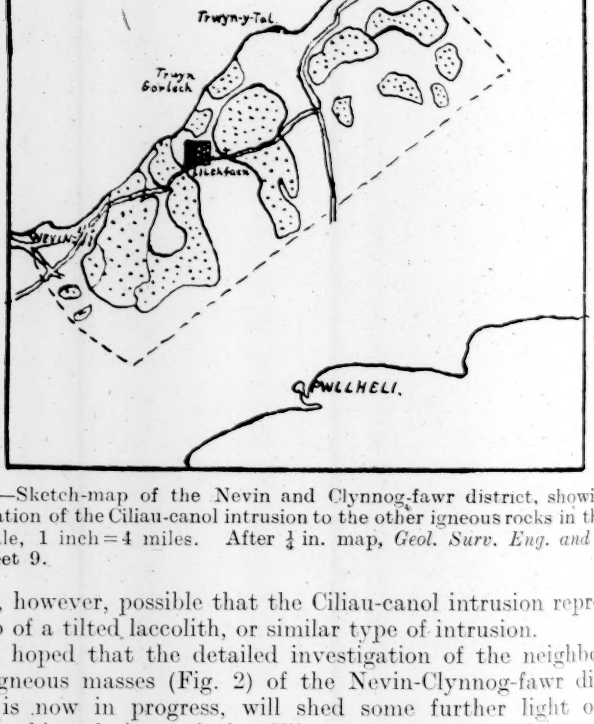


FIG. 2.—Sketch-map of the Nevin and Clynnog-fawr district, showing the relation of the Ciliau-canol intrusion to the other igneous rocks in the area. Scale, 1 inch = 4 miles. After ¼ in. map, *Geol. Surv. Eng. and Wales*, Sheet 9.

It is, however, possible that the Ciliau-canol intrusion represents the top of a tilted laccolith, or similar type of intrusion.

It is hoped that the detailed investigation of the neighbouring large igneous masses (Fig. 2) of the Nevin-Clynnog-fawr district, which is now in progress, will shed some further light on the petrographic relations of the Ciliau-canol intrusion.

[1] R. H. Rastall, *Q.J.G.S.*, vol. lxii, 1906, p. 253. A. Heard, GEOL. MAG., Vol. LIX, 1922, p. 359.

A New Fossiliferous Deposit in West Sussex.

By J. C. Ferguson, University College, London.

At the southern end of Thorney Island, about three miles S.S.W. of Emsworth, in West Sussex, there are low cliffs of London Clay covered by Pleistocene deposits. The London Clay has been folded near the top, and its surface presents a series of basin-like depressions, 3 to 10 feet in diameter, and evidently caused by downward pressure. These basins are occupied by Pleistocene gravel, which contains numerous erratics—many of igneous rocks—and resembles the better-known Erratic Gravel of Selsey. The Erratic Gravel is covered by Coombe Rock and Brickearth, which form the top of the cliff, as shown in the diagram.

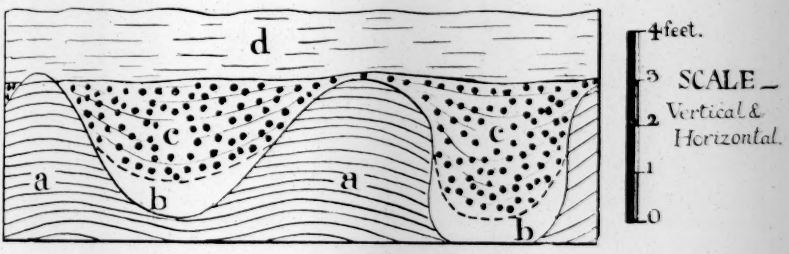


Fig. 1.—Diagram of cliff-section, Thorney Island. a, London Clay; b, green clay with fossils; c, erratic gravel; d, Coombe rock and brickearth.

As a rule, the Erratic Gravel rests directly on the London Clay, but, during the summer of 1922, the rapid erosion which the cliffs are undergoing revealed another deposit in about six of the basins, all adjacent ones. This new deposit comes between the London Clay and the Erratic Gravel; it is a green and yellow clay, with light calcareous patches, occupying the bottoms of the basins and spreading some way up their sides. This clay contains occasional small erratics and flints, and is full of shells, many of which are broken and worn. These fossils, for the identification of which I am indebted to Mr. C. P. Chatwin, are: *Ostrea edulis* Linn., variety, *Chlamys* (*Pecten*) *varius*, and *Trochus cinerarius*. The oysters are very abundant, and the Pectens fairly so, but only one specimen of the last-named fossil was found, despite careful search.

The boundary between the London Clay and this Green Clay-with-fossils is everywhere very distinct; in most places it is marked by a crack, along which the two deposits readily separate. On the other hand, there is no distinct boundary between the Green Clay and the Erratic Gravel, but the clay merges imperceptibly into the gravel.

The Riebeckite Granophyre of Ailsa Craig.

By Ashley G. Lowndes, M.A., F.G.S., Marlborough College.
(Late Head Microscopist, Nobel's Explosives Co., Ardeer.)

DURING the War a considerable amount of work of a somewhat geological nature was done in the laboratories of Nobel's Explosives Co., chiefly in connexion with providing acid-resisting material for use in the sulphuric and nitric acid plants.

This work involved the chemical analysis of many rocks both igneous and sedimentary, and included among others the famous riebeckite-granite or granophyre of Ailsa Craig.

The analysis was as follows:

SiO_2	69·40
Al_2O_3	15·73
Fe_2O_3	3·21
CaO	·21
MgO	·00
K_2O	5·76
Na_2O	4·75
	99·06

It has occurred to me that this analysis is of general interest and I am grateful to Mr. William Rintoul, F.I.C., Manager of Research of Nobel's Explosives Co., for permission to publish it.

New Fossils from Girvan.

By F. R. Cowper Reed, Sc.D.

(PLATE XII.)

Genus Cornulites Schlotheim.

SINCE the establishment of the two genera *Tentaculites* and *Cornulites* by Schlotheim in 1820 their relations have frequently been discussed, but no general agreement has been reached, and their characters have been differently defined by various authors, so that the generic position even of well-known species is rather an open question. For instance, the proper reference of "*Tentaculites*" *anglicus* Salter is still somewhat undecided.[1]

In connexion with British species one of the latest writers on the subject is Vine,[2] who in 1882 described certain forms from the Wenlock Shales, placing some of the species in one genus and some in the other. Both genera were referred by him to the tubicolous annelids, and he entered with some detail into the whole question of the separation of these genera, but without arriving at completely satisfactory conclusions. To a great extent he adopted Nicholson's[3]

[1] Vine, *Quart. Journ. Geol. Soc.*, vol. xxxviii, 1882, pp. 379, 387; Foerste, *Proc. Boston Soc. Nat. Hist.*, vol. xxiv, 1889, p. 276.

[2] Vine, op. cit., pp. 377–92, pl. xv.

[3] Nicholson, *Amer. Journ. Sc.*, ser. III, vol. iii, 1872, p. 202.

earlier views, but he gave amended definitions of the genera as follows :—

Cornulites.—" Tube annulated, striated longitudinally, attached by some portion of its extremity to foreign bodies." Further on he stated that the animal is solitary, inhabiting a tube of carbonate of lime which has " very thick walls composed of numerous imbricating conoidal rings, their widest end next the slender base and subirregular in old specimens, more or less distorted or oblique in the young ; external surface obscurely annulated, finely striated longitudinally ; inner surface and casts scalariform, with two or three longitudinal furrows ".

Tentaculites.—" Tube annulated, devoid of longitudinal striæ or of cellular structure, conical, straight, tapering towards one extremity and wholly unattached to any foreign body." Nicholson (op. cit., p. 206) specially remarks that the shell is thin. On the other hand Barrande [1] stated that in most species of *Tentaculites* longitudinal striæ are present, and he also observed that in certain cases the internal casts do not agree with the outer surface of the test and simulate the appearance of *Cornulites*. Hall,[2] moreover, had described in 1859 an internal cast of *Tentaculites elongatus* which possessed the imbricating segmental rings of *Cornulites* to which Barrande alludes. The internal structure of *T. annulatus* Schlotheim [3] from the Silurian of Gotland, which is the type species of the genus *Tentaculites* Schlotheim, does not appear to have been ever investigated or described, and we may doubt if the thin-shelled closely annulated forms, such as *T. elegans* Barrande [4] of the Lower Devonian of Bohemia, belong to the same genus as the thick-shelled Silurian species.

Most species of *Tentaculites* are described as straight, and all of them as free and unattached, but some shells which have been referred to this genus are curved, e.g. *T. curvatus* Boll [5] and *T. incurvus* Shumard,[6] though the last-mentioned species has been referred by Hall [7] and Savage [8] to *Cornulites*.

The type species of *Cornulites* Schlotheim is *C. serpularius* Schlotheim [9] ; this is annulated, curved, more or less twisted, and attached, and it occurs usually in groups of two or more individuals. In 1864 Ludwig [10] defined the genus in the following manner : Shell small, with transverse section circular, closed at base [= apex],

[1] Barrande, *Syst. Silur. Bohême*, vol. iii, pp. 110–34.
[2] Hall, *Palæont. New York*, iii, 1859, p. 136, pl. vi, figs. 16–21.
[3] Schlotheim, *Petrefact.*, 1820, p. 377, pl. xxix, fig. 8*a* (*non* 8*b*) ; Moberg & Grönwall, *Kungl. Fysiogr. Sällsk. Handl.*, Bd. 20, No. 1, 1909, p. 46, t. ii, fig. 1.
[4] Barrande, op. cit., p. 131, pl. xiv, figs. 20–7.
[5] Boll, *Zeitschr. deut. Geol. Gesell.*, Bd. viii, 1856, p. 321.
[6] Swallow, *Second Ann. Rept. Geol. Surv. Missouri*, 1855, p. 195, pl. B, fig. 6.
[7] Hall, *Palæont. New York*, vol. vii, Suppl., 1888, p. 18, pl. cxv, fig. 31 ; pl. cxvi, fig. 31.
[8] Savage, *Bull.* 23, *Geol. Surv. Illinois*, 1913, p. 41, pl. ii, fig. 7.
[9] Schlotheim, op. cit., p. 378, pl. xxix, fig. 7.
[10] Ludwig, *Palæontographica*, xi, 1864, p. 317, t. l, fig. 4.

having closed annulations, without longitudinal slit or operculum. The test is composed of imbricating hollow cones of which the larger aperture is directed towards the base and which fit into one another. The internal cast appears to be composed of a series of steps or segments and is not smooth. Ludwig's specimens came from the Devonian, but Schlotheim's type, as stated above, came from the Silurian of Gotland. Barrande (op. cit., pp. 167–74) quotes this definition and apparently adopts it. But it does not agree with that given by Vine. Ludwig figured as an example of *Cornulites* a shell from the Devonian to which he applied the name *C. scalaris* (Schloth.), although Schlotheim put this species in his genus *Tentaculites*; the figure shows a straight shell, with the internal cast composed of imbricating conical rings corresponding with the annulations on the surface.

Hall (op. cit., 1888, pp. 8–24) discussed the general structure of *Cornulites*, particularly the minute internal structure of the shell itself, and believed that in the early stages the tube was smooth, the annulations being developed later, but becoming obsolete with the growth of the animal; and that the longitudinal striæ which are at first obscure persist after the annulations are lost. In the early stage he stated that the organism is attached and parasitic, but in an advanced state of growth it is free and unattached. The present author is not, however, prepared to adopt Hall's views in their entirety, particularly in regarding *Ortonia* and *Conchicolites* as synonyms for *Cornulites*.

Nicholson [1] in 1890 introduced some modifications of his earlier views of the characters of *Tentaculites*, stating that the internal cavity is sometimes crossed by transverse partitions and that longitudinal as well as encircling striæ are occasionally present. But he maintained that the shell was invariably free and that the microscopic structure of the tube was totally unlike that of *Cornulites*.

Grabau [2] in 1899 gave a fresh definition of *Tentaculites* as follows: "Shell straight, elongate attenuately conical tubes, their surfaces marked by strong rings or annulations which are closely arranged near the apex and more distant and stronger near the mouth. Fine transverse and rarely longitudinal striæ are present." The same author in 1901 [3] defined *Cornulites* as follows: "Tube gently tapering, flexuous, the small end usually bent. The tube is either wholly or in part adherent to other objects. Walls thick, cellular, composed of imbricating rings. Surface ornamented by annulations and longitudinal striæ. Interior presenting a succession of annular constrictions giving a scalariform character to the cast."

Clarke & Ruedemann [4] in their figures of the internal cast of

[1] Nicholson, *Trans. Edinburgh Geol. Soc.*, vol. vi, 1890, pp. 66, 67.
[2] Grabau, *Bull. Buffalo Soc. Nat. Sc.*, vol. vi, 1899, p. 282.
[3] Ibid., vol. vii, 1901, p. 161.
[4] Clarke & Ruedemann, *Mem. New York State Mus.*, N.S., 1903, p. 105, pl. iv, figs. 1–5.

C. arcuatus Conr. from the Guelph Limestone clearly showed the imbricating nature of the successive segments of the internal cast, but in this case there are no corresponding annulations on the exterior.

Many of the American shells originally referred to *Tentaculites* are now placed in the genus *Cornulites*, and reference to some of them is made below.

The specimens from Girvan which have been put into my hands by Mrs. Gray combine some of the characters found in *Tentaculites* with others of *Cornulites* as defined by Vine, for the shells are free and unattached as in the former, but have the longitudinal striæ or lines on the test and the imbricating segmental structure which are said to mark *Cornulites*; they are also mostly more or less curved, which is unknown or unusual in true *Tentaculites*. A careful examination of the exterior of the shell of all the species described below shows that the annulations are really caused by a thickening of the lower or overlapping edge of each segment, and in a natural longitudinal section of the shell these annulations are thus seen to be not symmetrical rings even externally in cross section, the concave curve of their surface being long and gradual on the upper side, but steep and short on the lower side so as to make nearly a right angle with the surface of the next lower segment towards the apex. This imbricating segmental structure is much more clearly visible in internal casts, but it is obvious in both cases that the annulation is only marginal and belongs solely to the upper and overlapping segment.

The segmented nature of these shells appears sufficient to place them definitely as members of the *Annelida tubicola* and to separate them from the *Pteropoda*.

The question of the generic position of the other British species of "*Tentaculites*" cannot be discussed here.

The specimens which are described in the present paper have been collected at Girvan from time to time by Mrs. Gray, of Edinburgh; most of them are now in the British Museum and the reference numbers are given in parentheses. A few additional specimens which were found by Mrs. Gray in 1921–2 have also been examined by me, and some are figured.

Cornulites girvanensis sp. nov. (Plate XII, Figs. 1–3.)

Shell elongated, subcylindrical, gently curved, tapering very slowly at about 1 in 12 in the upper two-thirds of its length and then rather more rapidly and with stronger curvature to apex, composed of 20–35 segments, and marked by strong concentric annulations of which those on the upper two-thirds are set at fairly regular distances apart, equal to about half or two-thirds or nearly the whole diameter, while those in the apical third of the shell are more closely crowded. Segments short, slightly conical, forming imbricating rings successively overlapping each other from above, each having a gently

concave surface, with the lower edge of the segment swollen and rising rather suddenly into a prominent subangular marginal annulation which is more or less abruptly truncated below and descends steeply to next segment; each segment is ornamented with 4–6 narrow low faint concentric rings, frequently indistinct, and the whole shell is covered with regular equidistant fine thread-like raised longitudinal lines of rather unequal strength crossing the interspaces and annulations without interruption. A few faint low broad concentric lines are usually visible in each interspace.

Dimensions.	I	II
Length on curve	26·5 mm.	*c.* 38 mm.
Diameter at mouth	3·5 mm.	4 mm.
Number of annulations in upper two-thirds of shell	14	18
Ditto in apical third	11	*c.* 16

Horizon.—Saugh Hill Group (Middle Llandovery).

Locality.—Woodland Point (A. 2451 to 2462, A. 2506 to 2508).

Remarks.—This species is represented by several fairly perfect specimens showing the structure and external ornamentation of the shell. The segmental nature is recognized even on the surface of the test by the relation and section of the annulations, the difference in the slope of their upper and lower surfaces being clearly seen on a careful examination of the exterior. The species is much like the so-called *Tentaculites anglicus* Salter in its ornamentation and annulations. Vine (op. cit., p. 379) suspected that some, at any rate, of the shells usually referred to the latter species should be placed in *Cornulites* and remarked on its resemblance in many ways to his *C. scalariformis*[1] of the Wenlock Shales. But the curvature of our Girvan shell is distinctive, and in this feature as well as in the crowding of the annulations towards the apex it bears a likeness to *Cornulites incurvus* (Shumard)[2] of the Girardeau Limestone (Upper Medinan) of Missouri as described by Hall, Keyes, and Savage,[3] and also to our new species *C. shallochensis* (see below).

Cornulites camreganensis sp. nov. (Plate XII, Figs. 4, 5, 5*a*.)

Shell elongated conical, straight or very slightly curved, tapering about 1 in 5 or 6, composed of numerous segments of equal or subequal length. Annulations narrow, subangular, moderately prominent, set at equal or subequal distances apart (i.e. about half the diameter) for nearly the whole length of shell, becoming rather more closely placed near apex. Interspaces gently concave, each with 2–6 strong distinct concentric narrow granulated lines. Whole

[1] Vine, *Quart. Journ. Geol. Soc.*, vol. xxxviii, 1882, p. 379, pl. xv, figs. 1, 9, 10.

[2] Swallow, *Second Ann. Rept. Geol. Surv. Missouri*, 1855, p. 195, pl. B, figs. 6*a–b*.

[3] Hall, *Palæont. New York*, vol. vii, Suppl., 1888, p. 18, pl. cxv, fig. 31; pl. cxvi, fig. 31; Keyes, *Missouri Geol. Surv.*, vol. v, pt. ii, 1894, p. 217, pl. xxxv, fig. 3; Savage, *Bull. 23, Geol. Surv. Illinois*, 1917, p. 97, pl. iv, fig. 7.

shell covered with faint longitudinal striæ, much weaker and finer than the concentric markings. In internal casts the segments are seen to be composed of imbricating rings of equal or subequal length with slightly swollen rounded lower edges corresponding to the annulations on the surface.

Dimensions.—Length, 10·5 mm. Diameter at mouth, *c.* 2·0 mm.

Horizon.—Camregan Group (Upper Llandovery).

Locality.—Camregan Wood (A. 2509 to 2511, A. 2473 to 2477).

Remarks.—This species has a much more conical shape and tapers more rapidly than *C. vinei* sp. nov. from Newlands (see below), and it has the annulations set at more equal and wider distances apart. The strong concentric granulated lines in the interspaces and the weakness of the longitudinal lines, which can only be indistinctly detected even with a lens, are further points of difference.

Cornulites mullochensis sp. nov. (Plate XII, Figs. 6, 6*a*, 7.)

Shell very slender, conical, slightly curved near apex, tapering in upper four-fifths at about 1 in 15, composed of very numerous segments. Annulations prominent, subangular, close and regularly equidistant in upper half of shell, being about one-third to one-fourth the diameter apart, but becoming further apart in lower half so as to be separated by interspaces from one-half to two-thirds the diameter. Interspaces strongly concave. Whole shell marked with strong raised longitudinal lines crossing the annulations and interspaces alike. In internal casts the segments show as imbricating nearly flat rings with very slightly swollen lower margins and are short and of equal length in the upper half, but become considerably longer towards the apex.

Dimensions.—Length, *c.* 14·0 mm. Diameter at mouth, *c.* 2·0 mm. Number of annulations, 30–40.

Horizon.—Mulloch Hill Group (Lower Llandovery).

Locality.—Mulloch Hill (A. 2512 to 2519, A. 2467 to 2472).

Remarks.—This species is distinguished by its slender form and by the close annulations and short segments in its upper half instead of in its lower portion as in *C. girvanensis*. The curvature of the shell is also much less marked and the longitudinal lineation is coarser than in that species. Owing to the thickness of the shell in *C. mullochensis* the external annulations seem to be rather lower (i.e. more apical) than the swellings along the base of the segments of the internal casts, as is seen in Figs. 6*a*. The same feature is conspicuous in *C. vinei* from Newlands (see below).

Cornulites shallochensis sp. nov. (Plate XII, Figs. 8, 8*a*.)

Shell elongated conical, gently curved, tapering slowly at about 1 in 6 or 7 towards apex. Segments short, marked by strong prominent angular or subangular annulations, of which those in the upper three-fourths of the shell are set at one-third to one-half the diameter apart at fairly regular intervals, but those nearer the

apex are more crowded together and the interspaces are consequently narrower. Interspaces concave, marked with very delicate fine longitudinal striations which seem to be continuous from segment to segment and to cross the annulations (which bear granules?) uninterruptedly.

Dimensions.—Length along curve, *c.* 18·0 mm. Diameter of mouth, 3·75 mm. Number of annulations, 22–24.

Horizon.—Whitehouse Group (Middle Bala).

Locality.—Shalloch Mill (A. 2482).

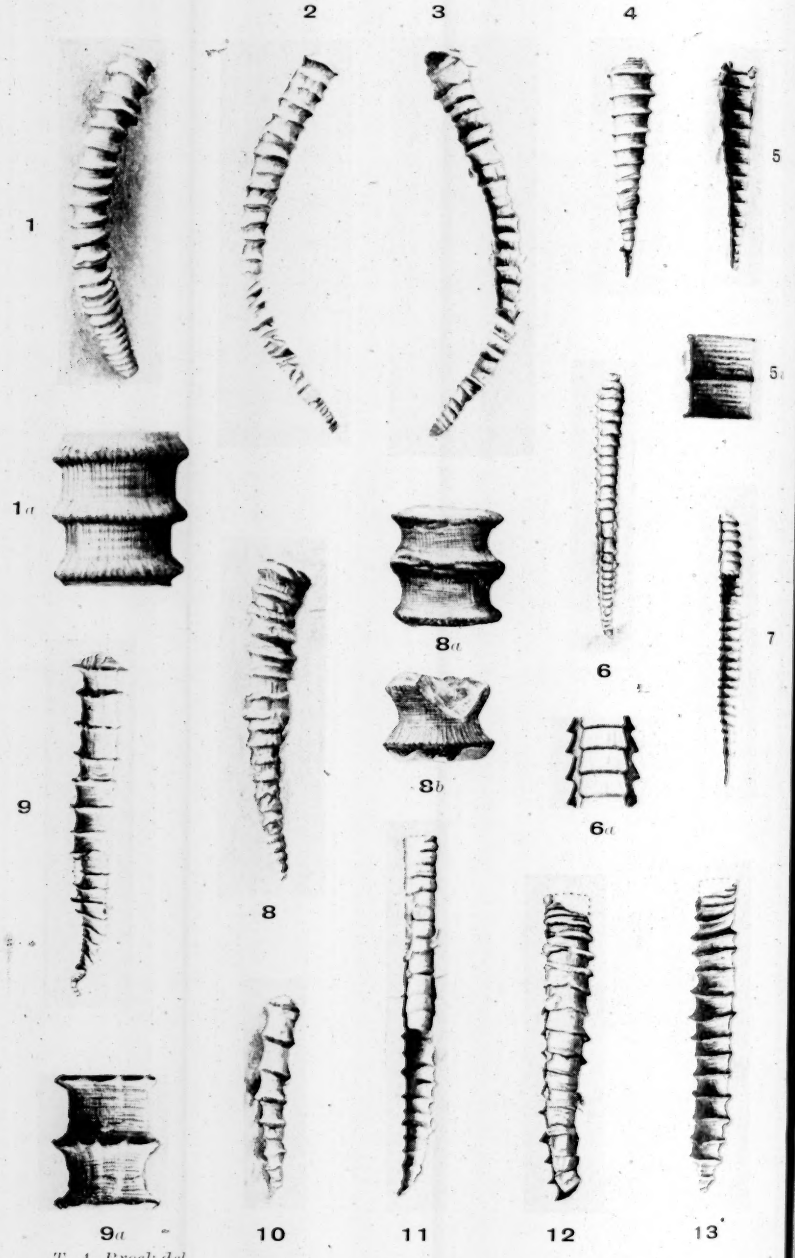
Remarks.—Only one good specimen of this species is known to me, and the last few rings of the apex of it are missing. Several fragments also occur in Mrs. Gray's recent collection. It differs from *C. girvanensis* in its more rapid tapering, the greater approximation of the annulations, and the much finer longitudinal ornamentation. Whether concentric lines are present or not is doubtful, but there are indications that the crest of the annulations bears granulations. The nature of the annulations and interspaces and their relations to the segments is as clearly visible in this species as in *C. girvanensis*. With regard to its further affinities we may specially mention *C. richmondensis* (Miller) from the "Hudson River Group" of Indiana.[1] Perhaps *C. tenuistriatus* (Meek & Worthen),[2] of the Cincinnati Group, is also allied.

Cornulites vinei sp. nov. (Plate XII, Figs. 9–13.)

Shell very slender and elongated, straight or gently curved near apex with occasionally a double bend at apex, subcylindrical for the greater part of its length but finally tapering slowly to apex; composed of numerous segments of equal or subequal length. Shell much thickened at annulations which are prominent angular or subangular, and smooth except for occasional swellings or wide crenulations of the crest; annulations set at fairly regular and equal distances apart, varying from half to two-thirds the diameter, but usually set much closer together near mouth. Interspaces strongly concave, ornamented with a few thicker concentric lines and more numerous very fine minutely granulated concentric striæ; a very delicate longitudinal striation is rarely visible. In internal casts the imbricating segments are mostly of regular size and cylindrical, with scarcely thickened basal edge, and have a length equal to or greater than the diameter owing to the thickness of the shell; the annulations on the external surface of the shell usually come below (i.e. nearer the apex) the basal edges of the segmental casts, particularly in the case of the middle and apical portions of the shell, thus causing an apparent non-correspondence of the segments and rings.

[1] Hall, op. cit., p. 18, pl. cxv, figs. 28–30, 33–9, and references in Bassler, *Bull.* 92, *U.S. Nat. Mus.*, vol. i, 1915, p. 280.

[2] Savage, *Bull.* 23, *Geol. Surv. Illinois*, 1917, p. 97, pl. iv, fig. 6.



T. A. Brock del.

CORNULITES FROM GIRVAN.

To face p. 275.]

Dimensions.—Length, *c.* 18·0 mm. Diameter at mouth, *c.* 1·5 mm. Number of segments in specimen, *c.* 30.

Horizon.—Saugh Hill Group (Middle Llandovery).

Locality.—Newlands (A. 2500 to 2505; A. 2463 to 2466; A. 2490 to 2499 Brit. Mus.; and Mrs. Gray's coll.).

Remarks.—Most of the specimens are imperfect or broken, but many have counterparts, and show the internal cast attached to part of the length of the hollow impression of the exterior, so that the reason for the apparent non-correspondence of the rings and segments is explained. The occasional sigmoidal curvature of the apex is remarkable. There is a close resemblance between this species and *C. mullochensis*, but the nodular ornamentation of the rings and the lineation of the interspaces are distinctive characters.

Cornulites sp.

One broken specimen of the upper part of the shell of some species of *Cornulites* is the only representative of the genus known to me from Penkill. It is rather a large form and tapers rather rapidly; a slight curvature is noticeable and the annulations which are low, broad, and subangular are set at rather unequal distances apart and seem to be rather oblique to the axis in one or two cases. The length of the fragmentary shell is 11 mm. and it possesses 7–8 segments; the diameter at the mouth is just 4 mm. and the rate of tapering is about 1 in 5. But no sufficient specific characters are present, though it seems separable from those above described.

Horizon.—Penkill Group (Tarannon).

Locality.—Penkill (A. 2488).

EXPLANATION OF PLATE XII.

FIG.

1.—*Cornulites girvanensis* sp. nov. × 2. Saugh Hill Group, Woodland Point, Girvan. (A. 2461, Brit. Mus.)

1*a*.—Ditto. Two segments of same specimen. ×6.

2.—Ditto. × 1½. Same horizon and locality. Mrs. Gray's Coll.

3.—Ditto. Impression of same specimen. × 1½. Mrs. Gray's Coll.

4.—*Cornulites camreganensis* sp. nov. × 3. Camregan Group, Camregan Wood, Girvan. (A. 2473, Brit. Mus.)

5.—Ditto. Impression of exterior. × 3. Same horizon and locality. (A. 2476, Brit. Mus.)

5*a*.—Ditto. Two segments of same specimen. × 6.

6.—*Cornulites mullochensis* sp. nov. × 3. Mulloch Hill Group, Mulloch Hill, Girvan. (A. 2468, Brit. Mus.)

6*a*.—Ditto. Internal cast of some segments of same specimen showing thickness of shell. × 6.

7.—Ditto. Impression of part of exterior with internal cast of upper segments. × 3. Same horizon and locality. (A. 2469, Brit. Mus.)

8.—*Cornulites shallochensis* sp. nov. × 2½. Whitehouse Group, Shalloch Hill, Girvan. (A. 2482, Brit. Mus.)

8*a*.—Ditto. Two segments of same specimen. × 6.

8*b*.—Ditto. Another segment of same specimen. × 6.

9.—*Cornulites vinei* sp. nov. Impression of exterior. × 3. Saugh Hill Group, Newlands, Girvan. (A. 2494, Brit. Mus.)

9*a*.—Ditto. Two segments of same specimen. × 6.
10.—Ditto. Apical portion of shell. × 3. Same horizon and locality. Mrs. Gray's Coll.
11.—Ditto. Shell showing part as internal cast and part as external impression. × 3. Same horizon and locality. (A. 2464, Brit. Mus.)
12.—Ditto. Upper (oral) part of another specimen, showing internal cast. × 3. Same horizon and locality. Mrs. Gray's Coll.
13.—Ditto. External impression of same specimen. × 3. Mrs. Gray's Coll.

The Base of the Devonian, with special reference to the Welsh Borderland.

By L. Dudley Stamp, B.A., D.Sc., A.K.C., F.G.S.

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I. Introduction.

In 1916 the writer carried out a field survey of a district in Shropshire in which the "passage beds" between the Silurian and "Old Red Sandstone" are well developed. So apparent was the difficulty of drawing a dividing line between the two systems that a description of the district was published without a decision being reached.[1] Shortly afterwards active service in France and Belgium brought opportunities of studying both field and museum evidence there. The writer came to conclusions which he afterwards found agreed very closely with those reached shortly before by MM. Barrois, Pruvost, and Dubois, who had approached the problem from a different standpoint.[2] A preliminary summary was published,[3] and in 1920 the Council of the Geological Society awarded the author the "Daniel Pidgeon Fund" for the purpose of enabling him to carry out a comparative study of the Downtonian and Gedinnian. The results were laid before the Society in November, 1921.[4] The Council have, however, declined to publish the paper, though their decision in this matter was not communicated to the author until nine months after the reading of the paper. A short

[1] Stamp, "The Highest Silurian Rocks of the Clun Forest District, Shropshire": *Quart. Journ. Geol. Soc.*, vol. lxxiv, 1918, pp. 221–44.

[2] Barrois, Pruvost, & Dubois, "Sur les couches de passage du Silurien au Dévonien dans le Bassin houiller du Pas-de-Calais": *C.R. Acad. Sci.*, vol. clxvii, 1918, p. 705.

[3] Stamp, "Note on the Determination of the Limit between the Silurian and Devonian Systems": Geol. Mag., Vol. LVII, 1920, p. 57.

[4] Stamp, "The Base of the Devonian, with especial reference to the Welsh Borderland": *Abs. Proc. Geol. Soc.*, No. 1075, November 19th, 1921, p. 6.

summary of the results obtained (but not of the field evidence) has been published in Belgium.[1] The main object of the present note is to place on record the field-work on which the general conclusions are based. One of the principal objections to the writer's conclusions which was raised when the paper was read before the Geological Society was that "the question where the line between the Silurian and the Devonian was to be drawn should be primarily determined in areas in which normal marine conditions had prevailed, not in one of exceptional character, like the Welsh Borderland".[2] This objection has now been removed by the publication of the Memoir on the Siluro-Devonian Faunas of Liévin.[3] Through the courtesy of the authors, the proofs of this work had been previously communicated to the writer. It will be seen in the sequel that the results of both lines of investigation have proved to be identical.

II. The Suggested Classification of the Siluro-Devonian Rocks of the Welsh Borderland.

The classification suggested for the Silurian and Lower Devonian rocks of the Welsh Borderland is as follows :—

Lower Devonian (O. R. S. Facies)	II. Dittonian.	
	I. Downtonian	"Red Downtonian" including the fish-beds of Trimpley and Ledbury.
		Temeside Shales.
		Downton Sandstone with *Platyschisma* Shales.
		Ludlow Bone-bed.
Silurian	III. Ludlovian	Upper Ludlow Group.
		Aymestry Group.
		Lower Ludlow Group.
	II. Wenlockian.	
	I. Valentian.	

VALENTIAN (Lapworth, 1876). This term is used in its original or usual sense as recently defined by Professor O. T. Jones.[4]

WENLOCKIAN. Used in the same sense as the Wenlock Series of Murchison (1834) or as defined with reference to the graptolite faunas by Miss G. L. Elles.[5]

LUDLOVIAN. This term is used to embrace the same rocks as the original Ludlow Series of Murchison (1834), with the exception

[1] Stamp, "La base du système dévonien en Angleterre": *Bull. Soc. belge Géol.*, vol. xxxi. 1921, pp. 87–98.

[2] *Abs. Proc. Geol. Soc.*, No. 1075, 19th November, 1921, p. 8.

[3] Barrois, Pruvost, & Dubois, "Description de la Faune siluro-dévonienne de Liévin": *Mém. Soc. Géol. Nord.*, vol. vi (II), pt. ii, 1920 (1922); see review in Geol. Mag., Vol. LX, 1923, p. 92.

[4] Jones, "The Valentian Series": *Q.J.G.S.*, vol. lxxvii, 1921, p. 144.

[5] Elles, "The Zonal Classification of the Wenlock Shales of the Welsh Borderland": ibid., vol. lvi, 1900, p. 370.

that the Ludlow Bone-bed is removed to the Downtonian. It thus includes the rocks from the Lower Ludlow Shales to the Upper *Chonetes* Beds (*Spirifer elevata* Shales of Elles & Slater[1]) inclusive. The Ludlovian is divisible into three groups :—

(i) Lower Ludlow Group—graptolitic shales described by Miss E. M. R. Wood (Dame Ethel Shakespear).[2]

(ii) Aymestry Group—defined by Miss Elles and Miss Slater,[1] comprising the *Dayia* Shales and Aymestry Limestone.

(iii) Upper Ludlow Group—used as defined by Elles & Slater, except that the Ludlow Bone-bed, placed by them at the top, is considered as forming the base of the succeeding Downtonian. The group comprises :—

(*b*) *Chonetes* Beds . .	{ Upper or *Spirifer elevata* Shales. Lower.
(*a*) *Rhynchonella* Beds.	

Details of these beds will be found in Elles & Slater's paper and in the writer's former paper.[3]

DOWNTONIAN (Lapworth, 1880, redefined by the Geological Survey of Scotland,[4] and applied to the Scottish succession in 1899; used with the same definition and applied to the English succession by Stamp in 1920[5]). The Downtonian may be briefly defined as the beds between the Ludlovian and the Dittonian or Lower Old Red Sandstone with the *Pteraspis-Cephalaspis lyelli* fauna. In a positive sense the Downtonian is the lowest division of the Devonian (Old Red Sandstone facies) and is characterized by the first appearance of a large number of genera and species of fish. If they occur at all, it is only very rarely that fish-remains are found in Pre-Devonian rocks. The commencement of the Devonian corresponds then with the dawn of an era of vertebrates. As contrasted with later series, the Downtonian is characterized by the abundance of Anaspidæ, Palæaspidæ, and simple Cephalaspidæ, and the absence of Pteraspidæ. The lower part of the Downtonian of the Welsh Borderland comprises a complex of shales, sandstones, and greenish rubbly shales (the Temeside Group of Elles & Slater). The thickness of this lower group rarely exceeds 500 feet. The upper part comprises a mass of red and green marls and sandstones with cornstone bands, which has only recently been separated from the Dittonian or Lower Old Red Sandstone with a *Pteraspis* fauna. The entire credit of the discovery of the great extent and thickness (probably never less than 1,500 feet in the central region

[1] Elles & Slater, "The Highest Silurian Rocks of the Ludlow District": ibid., vol. lxii, 1906, p. 195.

[2] Wood, "The Lower Ludlow Shales of the Welsh Borderland": ibid., vol. lvi, 1900, p. 415.

[3] Stamp, "The Highest Silurian Rocks of the Clun Forest District": ibid., vol. lxxiv, 1918, p. 221.

[4] Peach & Horne, "The Silurian Rocks of Britain: Vol. I, Scotland": *Mem. Geol. Surv.*, 1899.

[5] Stamp, op. cit., 1920.

of Shropshire) is due to Mr. W. Wickham King. The author is greatly indebted to Mr. King for permission to incorporate here some of his results, as yet unpublished. The present paper is restricted to a detailed study of the lower part of the Downtonian.

DITTONIAN (W. W. King, 1921). This name has been proposed to embrace the remainder of the Lower Old Red Sandstone of the Welsh Borderland, after the removal of the lower 2,000 feet or more, which has now been shown by its fish fauna to be of Downtonian age. The Dittonian is named from Ditton Priors, Shropshire, and is characterized by the presence of *Pteraspis rostrata, Pteraspis crouchii, and Cephalaspis lyelli.*

III. Historical Summary of the Siluro-Devonian Junction Controversy.

Having now outlined the classification used in this paper, some details may be added concerning previous attempts to define the limit between the Silurian and Devonian Systems. Murchison originally fixed the lower limit of the Old Red Sandstone below the Downton Castle Sandstone, i.e. at the horizon of the Ludlow Bone-bed.[1] The term "Silurian" was actually proposed for the first time by Murchison in 1835 to include "a complete succession of fossiliferous strata interpolated between the Old Red Sandstone and the oldest slaty rocks".[2] He had in the previous year, however, already divided that series into four groups—Ludlow Rocks, Wenlock and Dudley Rocks, Horderley and May Hill Rocks, and Builth and Llandeilo Flags.[3] At the time of the introduction of the term "Silurian" the Old Red Sandstone itself was divided into three groups[4]:—

(*c*) Conglomerates and Sandstones.
(*b*) Cornstones and marl.
(*c*) Tilestones, including the Downton Castle Building Stone.

The discovery of brachiopods and other Ludlovian fossils in the Tilestones led Murchison somewhat later (1848) to include these beds in the Silurian. Nevertheless, he long continued to regard the Tilestones as naturally forming part of the Old Red Sandstone, or as beds capable of being grouped with either the Silurian or the Old Red Sandstone. In the "Silurian System" (1838–9) even the Fish-bed and the Fucoid-bed are regarded as belonging to the "upper beds forming the downward passage from the Old Red System". In the later editions of Siluria the "highest member of the Ludlow rocks" is the Ludlow Bone-bed,[5] whilst the Tilestones are the "uppermost layers of the whole Silurian System and which form a transition into the Old Red Sandstone".[6]

[1] *London and Edinburgh Philosophical Magazine*, N.S., vol. vii, pp. 45–52.
[2] *Silurian System*, 1839, p. 7.
[3] *Proc. Geol. Soc.*, vol. ii, pp. 9–13 (8th January, 1834).
[4] Op. jam. cit., 1834.
[5] *Siluria*, 4th edition, 1867, p. 133.
[6] Ibid., p. 134.

TABLE SHOWING THE DIFFERENT CLASSIFICATIONS OF THE SILURO-DEVONIAN BEDS OF SHROPSHIRE.

Murchison, 1834–5. (1)	Murchison, 1848–67. (2)	Phillips, 1848. (3)	Page, 1856–76. (4)	Prestwich, 1887. (5)	Elles and Slater, 1906. (6)	King and Lewis, 1917. (7)	Stamp, 1918. (8)	Barrois, Pruvost, Dubois, 1918–22. (9)	Stamp, 1920. (10)	Stamp, 1921–2. (11)	
						L.O.R.S.	? L.O.R.S.	L.O.R.S.	L.O.R.S.	Dittonian.	
Lower Old Red Sandstone Marls	L.O.R.S.	L.O.R.S.	L.O.R.S.	L.O.R.S.	L.O.R.S.	R.D.	?	(R.D.)	R.D.	Red Downtonian	Downtonian
					T.S.	T.S.	T.S.	T.S.	T.S.	Temeside Shales	Downtonian
Tilestones.	T. D.S.	D.S.	T. D.S.	D.S.	D.S.	D.S.	D.S.	D.S.	D.S.	Downton Sandstone	Downtonian
L.B.B.	L.B.B.		L.B.B.	L.B.B.	L.B.B.	L.B.B.	L.B.B.	L.B.B.	L.B.B.	Ludlow Bone-bed	Downtonian
Upper Ludlow Rock.	U.L.R.	U.L.S.	U.L.	U.L.	C.B.	C.B.	C.B.	C.B.	C.B.	*Chonetes* Beds.	Ludlovian
					R.B.	R.B.	R.B.	R.B.	R.B.	*Rhynchonella* Beds	Ludlovian
Aymestry or Ludlow Limestone.	A.L.	A.R.	A.L.	A.L.	A.G.	A.G.	A.G.	A.G.	A.G.	Aymestry Group	Ludlovian

A.L. = Aymestry Limestone; A.R. = Aymestry Rock; A.G. = Aymestry Group; U.L.R. = Upper Ludlow Rock; U.L.S. = Upper Ludlow Shale; U.L. = Upper Ludlow; R.B. = *Rhynchonella* Beds; C.B. = *Chonetes* Beds; L.B.B. = Ludlow Bone-bed; D.S. = Downton [Castle] Sandstone; T. = Tilestones; T.S. = Temeside Shales; R.D. = Red Downtonian; L.O.R.S. = Lower Old Red Sandstone. The heavy black line shows the limit between the Silurian and Devonian adopted by the different authors.

(1) *Proc. Geol. Soc.*, London, vol. ii, 1834, p. 13. (2) *Siluria*, 4th ed., 1867, pp. 133–4 and 142. (3) *Mem. Geol. Surv.*, vol. ii, pt. i, 1848, pp. 84–103. (4) *Advanced Text-book of Geology*, 1st ed., 1856; 6th ed., 1876, p. 213. (5) *Geology, Chemical, Physical, and Stratigraphical*, vol. ii, 1888, p. 59. (6) *Q.J.G.S.*, vol. lxii, 1906, pp. 195–8. (7) *Proc. Birmingham Nat. Hist. Phil. Soc.*, vol. xiv, 1917, p. 90. (8) *Q.J.G.S.*, vol. lxxiv, 1918–19, pp. 221–46. (9) *C.R. Acad. Sci.*, vol. clxvii, 1918, p. 705, emended in *Mém. Soc. géol. Nord.*, vol. vi, ii, 1920–2, pp. 187–8. (10) Geol. Mag., Vol. LVII, 1920, p. 164. (11) *Bull. Soc. belge Géol.*, vol. xxxi, 1921, p. 88; *Abs. Proc. Geol. Soc.*, No. 1075, p. 6.

In other words, Murchison never included the Tilestones in the *Ludlow* Beds, but when he placed them in the Silurian he considered them as a higher series.

Since the time when Murchison included the "Tilestones" in the Silurian System, the upper limit of the latter has been gradually moved higher and higher as higher and higher beds have yielded marine fossils. In England certain fish-remains occurred in association with these marine fossils. Consequently, when similar fish-remains were found in Scotland the beds containing them were removed from the Old Red Sandstone and classed as Silurian. Similarly, in England the same "Downtonian" fish-fauna was found to persist long after the marine fossils had disappeared, but owing to the entity of the fish-fauna the whole series of beds had perforce to be considered as Silurian (Ledbury Passage Beds and Red Downtonian).[1] This important point is frequently ignored by those who advocate a high limit for the Silurian.[2] Whilst it is practically impossible to draw the dividing line between the two systems in the midst of the Downtonian—which forms a faunally and stratigraphically homogeneous series—the top of that series is at least 1,500 feet *above* the higher limit adopted by Murchison for the Silurian. The accompanying table shows at a glance the curious way in which the boundary line between the Silurian and the Old Red Sandstone has been repeatedly changed. It may be noted that as early as 1856 there was a reaction in favour of considering the Ludlow Bone-bed as the base of the Old Red Sandstone, and Page maintained this opinion in spite of the opposition of Murchison (see also Banks' conclusions, quoted on page 29). Other authors—notably Prestwich—urged that the Bone-bed must at least be grouped with the Downton Sandstone and not with the Ludlow.

The whole question has been discussed from the historical standpoint by H. de Dorlodot in connexion with the problem of the base of the Devonian in the Ardennes.[3] He shows very clearly that unless one adopts the original limit of Murchison (1834–5) then Dumont's definition of the base of the Rhénan (Devonian) in the Ardennes (1845) has prior claim over Murchison's later redefinition of the upper limit of the Silurian (1848). Similar conclusions have been expressed by H. S. Williams in America,[4] and by Barrois, Pruvost, & Dubois in France.[5]

[1] Professor Hull attempted to overcome the difficulty by the creation of a "Siluro-Devonian System" to include the passage-beds above the Ludlow Bone-bed. *Q.J.G.S.*, vol. xxxviii, 1882, p. 200.

[2] Leriche, "Observations sur la limite entre le Silurien et le Dévonien . . . à propos d'une note de M. Stamp": *Bull. Soc. belge Géol.*, vol. xxxi, 1921, pp. 158–66.

[3] de Dorlodot, "Le Système dévonien et sa limite inférieure": *Ann. Soc. géol. Belg.*, vol. xxxix, 1912, Mém., pp. M 291–M 371; also Conclusions . . . , ibid., Bull., pp. B 242–5.

[4] Williams, *Bull. Geol. Soc. Amer.*, vol xi, 1900, pp. 334–5.

[5] Op. cit., 1920 (1922), pp. 205–16.

The classification adopted in this paper, by restoring the original lower limit of the Old Red Sandstone, satisfies the laws of priority both with regard to the Silurian and Old Red Sandstone in this country, and also, as will be seen in the sequel, with regard to the Rhénan (Devonian) on the Continent. It should be noted, however, that the dividing line is to be drawn definitely below the Ludlow Bone-bed.

(*a*) The Bone-bed is indissolubly linked with the succeeding sandstones by its fish-fauna. There is not one species of fish recorded from the bed which does not occur also in higher strata, whereas it is doubtful whether a single one has ever been found in lower beds.

(*b*) The Upper Ludlovian marine species which occur in the Bone-bed all range upwards into the overlying strata. Several characteristically Downtonian invertebrates occur for the first time in the Bone-bed.

(*c*) The Bone-bed passes laterally into an osseous conglomerate and then into ordinary conglomeratic sandstones which rest unconformably on underlying beds (even down to Cambrian).

(*d*) The lithological change is at this horizon.

(*e*) It is now customary to consider similar Bone-beds as the base of formations or systems (e.g. the Rhaetic Bone-bed).

(*To be continued.*)

REVIEWS.

Special Reports on the Mineral Resources of Great Britain. Memoirs of the Geological Survey.

Vol. XXV.—Lead and Zinc Ores of Northumberland and Alston Moor. By Stanley Smith, with contributions by R. G. Carruthers. pp. iv + 107, with 15 figures, 1923, price 3*s.* 6*d.* net.

Vol. XXVI.—Lead and Zinc Ores of Durham, Yorkshire and Derbyshire, with Notes on the Isle of Man. By R. G. Carruthers and Sir A. Strahan. pp. iv + iii, with 2 plates and 6 figures, 1923, price 3*s.* net.

WE welcome two further volumes of these admirable publications, dealing with the Pennine district in general, a region of particular interest to the geologist, both general and economic, with a wealth of associations with the earliest days of mining in this country. Dr. Stanley Smith makes a striking point in calling attention to the fact that the Roman Wall is situated exactly at the northern limit of the productive mining field, a coincidence too remarkable to be accidental. As is well known the Romans mined extensively both in the extreme north and in Derbyshire, and until the great industrial depression of the present years, mining, first mainly for lead and of late for zinc, has been of great importance. The recent considerable demand for fluorspar has enabled a certain amount of production to continue even under the most adverse circumstances, but of course a good deal of this has come from old dumps.

Both these memoirs give very full descriptions of the mineral

veins, flats, pipes and other characteristic structures, which may indeed be regarded as the type examples of lead-zinc ore-bodies in limestone. It is of much interest to note that in the north the payable parts of the veins are confined to high levels, in fact to hill-tops, the veins becoming barren where the outcrops descend into the valleys. This suggests that the mineralization was related to an older surface, now deeply dissected. From the practical point of view this fact of observation is most discouraging as regards further developments at greater depths, but the discovery of rich ore far below the surface in the Bradford Corporation aqueduct tunnel at Greenhow, near Pateley Bridge, is a good sign in the other direction.

All students of ore-deposits and of general geology will find much to interest them in these volumes, which will enhance the already high reputation of the series of the Special Reports on the Mineral Resources of Great Britain.

R. H. R.

Die Kriegsschauplätze 1914–1918 geologisch dargestellt; Heft 5. Argonnen und Champagne. By Dr. K. Hummel. Giessen, pp. 82, with six text-figures. Berlin: Borntraeger, 1923.

DURING the war a large number of German geologists were employed as technical advisers on the various fronts: the material then collected is now being published in a series of thirteen monographs, under the general editorship of Dr. Wilser of Freiburg i. Br. The part under review contains a comprehensive and detailed account of the geology of the well-known district of the Argonne and Champagne, including sections on physiography and hydrography, on general stratigraphy and the geological history of the district, and on the economic products. A bibliography of 75 items is a useful feature for those interested in the geology of the eastern part of the Paris Basin and the southern border of the Ardennes, these being the chief structural features included in this area. The account of the Jurassic and Cretaceous strata is very full and complete and the description of the superficial deposits occupies some twelve or thirteen pages. Much detail is given as to the water-supply, water-bearing strata and other points of immediate military interest. The work should be of considerable value during the next war.

The Geology of the Namma Coal Field, Burma. By E. Moldenke. Trans. Amer. Inst. Min. Met. Eng., vol. lxvi, 1922, pp. 299–302.

HITHERTO all coal used in Burma has been imported from Calcutta, and is consequently very expensive. There are, however, lignite deposits in the country, the most promising being the Namma field in the Northern Shan States, 30 miles south of

Lashio, the terminus of the Burma Railway, 750 miles N. of Rangoon. The lignite basin, covering about 50 square miles, consists of Tertiary strata overlying Devonian limestone. There are two chief beds of lignite, the upper one averaging about 14 feet, and the lower one ranging from 19 to 40 feet, both consisting in depth of a lustrous black lignite with a dark brown streak: it contains fixed carbon 45 per cent, volatile matter 37 per cent, ash 4 per cent. A conservative estimate of the total resources of the basin assigns 50,000,000 tons to the lower bed and 30,000,000 tons to the upper. No mining has yet been done.

REPORTS AND PROCEEDINGS.

South Wales Institute of Engineers.

Friday, 27th April, 1923.

A. E. Trueman and J. H. Davies. The Correlation of the Coal Seams of the Anthracite area of the South Wales Coalfield.

Characteristic Mollusca were described from several seams in the neighbourhood of Brynamman and Ystalyfera. The species of *Carbonicola* characteristic of the Lower Vein of Brynamman have been located in various seams from Abercrave westwards to Pembrokeshire. The assemblage of *Carbonicola* spp. with *Anthracomya modiolaris* has been found from Abercrave to Ammanford and appears to be characteristic of the Peacock or Brass Vein. An assemblage of *Naiadites modiolaris* and *Carbonicola* spp. is characteristic of the Big, Nine-feet and Stanllyd seams of Brynamman, Ystradgynlais and Cross Hands. Characteristic forms of *Carbonicola* were described from the Four-feet (Cornish) vein of Ystradgynlais and this vein is correlated with the Green Vein of Cross Hands and Caerbryn, where similar shells are found.

These fossils will make possible the correlation of the north and south crops of the field and compare closely with those of certain zones in N. Staffs and elsewhere, placed by Wheelton Hind in his zone of *Naiadites modiolaris* and *Anthracomya modiolaris*. In both areas they are followed by a zone of *Anthracomya Phillipsi*.

Geologists' Association.

Friday, 4th May, 1923.

A lecture was delivered on "The Rock-shelters and Caves of Dordogne", by Arthur L. Leach, F.G.S.

Outline of the geological and geographical features of the district traversed by the R. Vézère. Les Eyzies—the "pre-historic capital of France". River-bluffs, *champignons*, *abris*, grottoes and caverns in the vicinity of Les Eyzies, illustrated by Roc de Tayac, Rocher de la Peine, Grande Abri de Laussel, Gorge d'Enfer, Grotte des

Eyzies and Font de Gaume. Laugerie Haute: method of excavation of the archæological deposits.

The road to Le Moustier: the plateau and the incised valley of the Grande Beune. Roque St. Christophe and its mediaeval fortress. Le Moustier: upper and lower rock-shelters: preservation of type-sections of the archæological deposits. La Madeleine rock-shelter. Illustrations of the palæolithic paintings and engravings of Combarelles and Font de Gaume. The mirror of the R. Vézère.

OBITUARY.

Frederic William Harmer, J.P., M.A., F.G.S., F.R.Met.Soc.

BORN 24TH APRIL, 1835. DIED 11TH APRIL, 1923.

The death of Mr. Harmer deprives us of a man of rare ability. Apart from his scientific attainments he was noted for his business capacity, and his labours in many fields. His work in his favourite science can alone be noticed here. He was one of the decreasing number of those who, not being connected professionally with geology, contributed in very full measure to its advancement. His reputation as a geologist extended beyond Britain, and many foreign geologists made special visits to this country to see him and profit from his knowledge.

His geological work lay chiefly among the newer deposits, and he devoted himself especially to a detailed study of the Pliocene and Pleistocene accumulations of East Anglia. His work among the Pliocene beds resulted in the publication by the Palæontographical Society of his Monograph of the Pliocene Mollusca, which was practically completed when he died. It shows his painstaking methods of detailed study and will be ever of high value. His work on the Pliocene led to a comparative study of the British and foreign strata and of the conditions in which they were laid down. In this work he is seen as a bold generalizer. The attention he paid to meteorology, in connexion with the conditions of formation of the Pliocene beds, is specially noteworthy.

The same capacity for combining generalization with specialization is seen in his Pleistocene work, and he produced a series of papers of high value dealing with this subject. He eventually summarized this work in a separate memoir on "The Glacial Geology of Norfolk and Suffolk".

Mr. Harmer served on the Council of the Geological Society, and in 1902 was awarded the Murchison Medal. He was honoured by more than one foreign Geological Society, and in 1918 the University of Cambridge conferred upon him the degree of M.A. *honoris causa*.

His kindness will long be remembered by his friends, and the ready help he gave to all who sought it should be recalled when we consider what he has done for the advancement of the science.

J. E. M.

Dr. C. I. Forsyth Major.

Dr. Charles I. Forsyth Major, F.R.S., whose death occurred on 25th March, at the age of 79, was the author of upwards of eighty memoirs published by the scientific societies of England, France, Italy, Germany, and Switzerland, on the later fossil Mammalia, their systematic morphology and geographical distribution. His work covered a wide range and included the exploration of the Tertiary, Post-Tertiary, and Recent mammals of Italy, Corsica, and Sardinia, the Miocene vertebrates of Samos, etc., and the Tertiary and Recent vertebrates of Madagascar. He discovered the first skeleton of the extinct bird *Aepyornis*, an extinct *Hippopotamus*, a giant lemur, *Megaladapis*, and a new type of ape, *Nesopithecus*, besides numerous other species. He amassed very considerable collections which were mostly deposited in the British Museum, where he was at one time temporarily employed. In his later years he spent much of his time in Corsica where he continued to pursue his palæontological studies. It is feared that much of his later work, such as that on the geological position of *Samotherium* and on the living Okapi will never be published.

Count F. de Montessus de Ballore.

BORN 1851. DIED 1923.

All students of the geological aspects of earthquakes are acquainted with the "Géographie Séismologique", a great work containing records of 160,000 earthquakes, and bringing out the principal facts regarding their distribution in space. A second general work "La Science Séismologique" appeared in 1907. In the same year the author was appointed director of the earthquake-service in Chile, which he conducted with great success. M. de Montessus de Ballore was undoubtedly in the first rank of the not very numerous scientific students of seismology, a subject whose development on modern lines owes much to his work.

CORRESPONDENCE.

THE ISLAY SUCCESSION.

SIR,—In *Proc. Geol. Soc. London*, 28th April, 1923, p. 77, Mr. George Barrow states that it is possible in discussions of Islay geology to start "from the base of the Quartzite (the Central Highland Quartzite) which occurs along nearly the whole of the south-eastern side of Islay, a little inland. Mr. Wilkinson gives the evidence that this is the base in great detail, the lowest part of the rock being often black, and at times containing slabs of underlying material (now a graphitic phyllite) fully a foot long".

Perhaps I may recapitulate in outline my reasons for disagreeing

with Mr. Wilkinson in this particular (*Q.J.G.S.*, vol. lxxii, pp. 152–5, and pl. xii).

In East Islay, for 8½ miles out of a possible 13, Mr. Wilkinson has mapped a band of slates separating the conglomeratic beds mentioned above from the main quartzite lying north-west of them. I have little doubt that fuller exposures would show this band of slates to be really continuous in Islay. At any rate, following in Mr. Wilkinson's footsteps, I have found it everywhere in a similar position in Jura, where its above-sea outcrop totals another 20 miles measured along the strike. The slates of this band I have called the Jura Slates. I agree with Mr. Wilkinson that appearances on the south coast of Islay strongly suggest that the conglomeratic group lying south-east of the Jura Slates has derived material through erosion of the latter. But I disagree with him when he declares that the Jura Slates are exposed along the crest of an anticlinal fold, and that the conglomeratic quartzite south-east of them is merely an outlier of the main quartzite farther north-west. My reasons are as follows :—

(1) There is no field-appearance suggesting the postulated fold.

(2) The Jura Slates along almost all their outcrop are assymetrical, with a grey division against the main quartzite and a black division against the conglomeratic group. (I can speak with certainty in regard to this feature in the southernmost exposure in Islay, and in all except one occurrence in Jura. At the extreme north of Jura, the group is wholly black. Unfortunately, I have no detailed notes regarding exposures in Islay, except the southern one figured op. cit., p. 154.)

(3) The conglomeratic group is everywhere distinguishable on the ground of texture, from the main quartzite occurring on the other side of the Jura Slate outcrop.

It will be seen, therefore, that the evidence which points to the conglomeratic group being later than the Jura Slates, places them at the original top, rather than the original base, of the Islay Quartzite taken as a whole.

E. B. Bailey.

Edinburgh.

PETROGRAPHIC NOMENCLATURE.

Sir,—I am led to stir up these muddy waters once more by reading Mr. Dixey's interesting account of the norite of Sierra Leone (Q.J.G.S., 1922, pt. 4). Some years ago (1918) I gave a brief account of this norite in the Geological Magazine (and, by the way, I wish Mr. Dixey had not said that I "translated Gürich's work", for the few observations that I described were my own), and I mentioned three facies, namely a pegmatitic norite, a medium-grained norite, and an aplitic norite or micronorite. Mr. Dixey recognizes the same three facies, but the rock that I called micronorite he calls beerbachite, and he gives the name norite-aplite to another rock which consists chiefly (sometimes almost wholly) of quartz, orthoclase, and acid plagioclase, with